ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

First Partial Report

On

PROJECT NO. 21, Determination of the Sources, Magnitude and Costs of Gunnery Errors

Project No. 21

24 May 1944

ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

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472.1 SPMEA

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1. PROJECT: No. 21, Determination of the sources, magnitude and costs of Gunnery errors; First Partial Report.

a. Authority: Letter, Office of Surgeon General 24 March, 1944.

b. Purpose: To obtain quantitative data to serve as a basis for critical evaluation of the capacities, limitations and expectations in firing on the move with the gyrostabilizer.

2. DISCUSSION:

a. The ability to maintain effective fire from a moving tank is clearly desirable, provided it can be obtained at a cost which does not outweigh the advantages gained. In order, therefore, to reach a meaningful conclusion as to the value of a particular method of securing moving fire, it is necessary to know its capacities and limitations in terms of quantitative measurement of the precision of fire which can be maintained.

b. The present apparatus for gun stabilization is limited in its capacity in that it provides for a degree of stabilization in elevation only and leaves entirely to the gunner the problem of controlling deflection. It is recognized, therefore, that the effectiveness of moving fire with this equipment cannot approach that of firing from the stationary tanks. The lack, heretofore, of any body of basic data relative to its capacities has made it difficult to assess its value and the cost of its employment,

c. It may be that the equipment has certain psychological value and usefullness as a weapon of opportunity. It is difficult, if not impossible, however, to obtain factual data upon its value when so employed. If the equipment is accepted for this use alone, then the basis for acceptance must be clearly understood and every precaution taken to avoid an erroneous idea of its capacities upon which the crew may depend for reduction of enemy targets in given combat situation.

d. In the present study, an attempt has been made to secure the required basic data upon which to evaluate the equipment, the conditions of test being set up and maintained to produce a highly favorable situation for use of the gyrostabilizer. As a basis for evaluation, the capacities and limitations of moving fire have been compared with those possessed by stationary fire and firing from the halt of short duration.

e. The study included evaluation of the performance of both the 75 mm gun with AP shot and HE and of the cal. 30 coaxial machine gun. Because of the clearly distinct uses of the two weapons, however, the results will be reported separately, the present report dealing with the 75 mm gun only.

f. The test procedures and results are presented in the Appendix.

3. CONCLUSIONS:

a. Under highly favorable conditions of operation, the comparative precisions of moving fire with the gyrostabilizer, firing from the halt and firing from the stationary tank at ranges from 200 to 1000 yards were as follows:

Type Fire	Probability of Hit on Tank Front Target (7 ft. by 7 ft.)		
	200 yds.	500 yds.	1000 yds.
Stationary	99+%	99+%	99+%
From halt	99+%	99+%	88%
Moving, with Gyro	82%	46%	19%
Moving, without Gyro	46%	18%	6.5%

b. Above probabilities apply only to operations with a highly skilled crew, excellent mechanical condition of equipment, favorable terrain, range being exactly known, and complete familiarity with nature of ground and appearance of target in advance. Under combat conditions, lesser probabilities of hits must be anticipated.

c. The effectiveness of fire in terms of hits per minute upon a tank front target for equal ranges and equal rates of advance was twice as great in firing from the halt as in moving fire, and in terms of halted time only, the number of hits per minute at 2000 yards from the halt was greater than at 500 yards when moving with the stabilizer in operation.

d. In situations requiring actual destruction of enemy targets no advantage to offset the reduced effectiveness of fire is seen in moving fire with the present stabilizing equipment over firing from the halt, either in terms of reduced vulnerability or greater rate of advance.

e. Against selected horizontal targets, the probability of effective hits with ricochet burst HE in moving fire at 500 yds. varied from 10% to 26% depending upon the sight employed. Chances of hitting within the target area were approximately doubled when firing from the halt.

f. The effectiveness of moving fire with present gun stabilization equipment was found to be seriously limited by the lack of stabilization in the horizontal direction and by the failure to achieve a high degree of vertical stabilization.

g. As a consequence of the limited stabilization, the time lag from the instant when the gunner decides to fire until firing actually takes place produces an inevitable error in aim which appears to account for as much as 70% of the dispersion of fire.

4. RECOMMENDATIONS:

That the data contained in the report be considered in decisions with respect to future use of the present stabilization equipment and in the development of tactical plans which involve firing on the move.

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#1 - Appendix with Tables 1 thru 8
#2 - Figures 1 thru 16c

APPENDIX

1. OBJECTIVES OF STUDY:

The function of the gyrostabilizer is to reduce the magnitude of angular travel of the gun sufficiently to permit effective firing on the move. Improvement is secured in vertical movement only, leaving the control of horizontal travel entirely to the gunner. It is evident, therefore, that full advantage has not been taken of the potential value of complete gun stabilization and the effectiveness of moving fire with present equipment cannot be expected to equal or even approximate that of stationary fire. This fact is recognized but the degree to which it limits the value of moving fire has not been fully evaluated in terms of absolute or relative effectiveness. It has not been possible, therefore, to express quantitatively the results that may be expected from firing on the move or to define the limited conditions under which it could be employed with profit. Clearly, such information is required in order to construct a basic tactical doctrine. It was the purpose of the present study to obtain such fundamental information. In order to secure reasonably comparable data and to determine the maximum usefullness of the equipment, the most favorable circumstances of use were deliberately selected for the tests. To this end, the following conditions were maintained:

a. The same highly skilled and experienced crew were employed throughout. They had considerable advance practice in the conduct of the tests.

b. The tank, gyrostabilizer, power traverse and other controls were maintained in first-class mechanical condition at all times.

c. Gun sights were adjusted as frequently as necessary to insure accuracy of alignment in every test.

d. The terrain was carefully selected to cause minimum disturbance to the vehicle and to remain substantially constant throughout the study.

e. For each test the exact range was known and the crew were well acquainted with the appearance of the target and the nature of the ground over which the tank moved.

These favorable test conditions must be kept in mind in considering the results obtained.

2. EQUIPMENT AND PROCEDURES:

a. Nature of tests.

(1) The relative effectiveness of fire was determined for:

(a) Stationary fire.

(b) Firing from halt.

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(c) Moving fire, with and without the gyrostabilizer

(2) The ranges employed were as follows:

Stationary	From Halt	Moving fire with gyro (mean range)	Moving fire without gyro (mean range)
		200 yds.	200 yds.
500 yds.	500 yds.	500 yds.	500 yds.
1000 yds.	1000 yds.	1000 yds.	
1500 yds.	1500 yds.		
	2000 yds.		

Firing from the stationary tank and from the halt were done at the specified ranges. The moving fire tests, however, were conducted over zones centered at the specified distances, the zones being 100, 200, and 300 yds. for mean ranges of 200, 500 and 1000 yds. respectively. All ranges were determined by tape measurements.

(3) Comparative tests were conducted with the periscopic sights M4 (1.44 power) and T8 (six and unit power) and telescopic sight M70 (3 power). The M4 periscopic sight was equipped with the M38 telescope having the older type reticle (C80438), whereas the T8 and M70 sights were provided with the new type. The lenses in the M70 sight were properly adjusted to optimum focus.

(4) Relative performance was determined for AP shot and ricochet burst HE (M48 fuse) with the 75 mm gun and cal. 30 ball with the coaxial machine gun. The present report deals only with the results with the 75 mm gun and the performance of the machine gun will be reported separately.

b. Equipment and Test Facilities.

(1) Terrain: The tests were conducted at Rolling Fork Range, Fort Knox, during March, April and May, 1944. The ground was essentially flat farm land, only moderately well drained. A general view of the terrain is shown in Fig. 1. Rain occurred frequently during the period of study so that the soil was saturated with water and was soft. Tank tracks penetrated to a depth of 6 inches and hence made definite but yielding ruts. An effort was made to avoid previous tracks in making a run during moving fire. This became increasingly difficult as the tests progressed but was kept at a minimum by frequent changing of target position. In general it may be said that the terrain was relatively favorable to stable tank performance insofar as irregularity of ground was concerned. In fact, yielding characteristics of the soil resulted in smoother operation of the gyrostabilizer and traverse than was possible when driving on a smooth gravelled road, as demonstrated by motion picture analysis of the movements of the gun and tank in relation to the target.

(2) Targets: The target for AP fire consisted in an approximate front silhouette of a German Mk IV tank, painted OD with a black central area 30" x 48". The target was centrally mounted, three feet from the ground, just behind a 30' x 20' vertical net, as shown in Fig. 2. The purpose of the

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net, which was barely visible to the gunner, was to permit accurate spotting of shots which missed the target. The elevation of the target above the ground permitted scoring of most shorts. In general, all rounds fired in a given test were accounted for as hits on the target or net.

(a) For ricochet HE fire, the target consisted in a 3' x 4' vertical cloth panel, O.D. in color, and mounted at ground level. Immediately back of it on the ground was laid a 12' x 12' black paper sheet, the purpose of which was to permit a rough assessment of the effectiveness of HE fire in relation to distance of center of burst from the target area, as indicated by damage to the paper sheet or penetration by fragments.

(3) Tanks: Two production models of the medium tank M4A3 were employed. Both were equipped with M34A1 gun mount, modified gyrostabilizer and oil gear power traverse. One vehicle was equipped with mount and linkage for sight T8. Both tanks were carefully serviced prior to starting the tests and properly maintained thereafter so that day to day results so far as they may be affected by these factors were comparable.

c. Conduct of tests.

(1) On the stationary fire tests, the tank was located at the desired range, sight adjusted and one or more rounds fired, if necessary, to establish accuracy of alignment. For scoring, 5, 10 and 15 rounds were fired at the three ranges of 500, 1000 and 1500 yds. No time restrictions were placed upon the gunner since the primary purpose of the tests was to establish a useful baseline of precision of the system--gun, ammunition, tank, sights and gunner.

(2) For moving fire the tank was driven with bow hatches closed at approximately 10 mph through the zone in as straight a line as possible. The gunner was instructed to start firing when the tank passed the starting zone flag and to continue until the end zone flag was reached. From practice runs the practical number of rounds that could be fired during the time of passage through the zones was established and effort was made to maintain these selected rates of fire during the tests. Owing to irregularities in ground, tank operation, and operation of gun controls, however, it was not possible to maintain the schedule exactly. In general, 40 rounds were fired in a complete test; this required from 6 to 10 trips through the zone, depending upon the sight employed. Tests with moving fire were conducted with the tank operating in two directions--directly toward the target and along a course 20° to the left of the target line.

(3) Firing from the halt proceeded as follows: The tank traveled at 10 to 20 mph to the center of the zone and came to a halt. The scheduled number of rounds were then fired, after which the tank proceeded at maximum speed out of the zone. The total time of travel through the zone and the actual halted time were recorded. Four, five and six rounds were

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fired per trip with the M70, M4 and T8 sights respectively and approximately 20 rounds were fired in a complete test.

d. Collection of data. Observations of temperature, humidity and wind velocity were regularly made and the relative visibility and position of the sun in relation to the target line recorded. The contrast between the target and background was low and remained essentially constant. The deposition of hits over the target and net area was determined in relation to horizontal and vertical reference lines so that the dispersion pattern could be described statistically for each test. Similarly, the distribution of centers of airburst from HE fire, as indicated on the ground, was determined in relation to the center line of fire and position of the target. In certain of the test moving picture records were obtained of the angular movement of the gun in relation to the target. From these records information was obtained respecting the relative stability of the gun at the time of firing and in addition, they provided a quantitative measure of the success with which a skilled gunner can track the target. Information with reference to the relative role of vertical as compared with horizontal movement (velocity and amplitude) was also provided by these photographic records. Other data collected included measurements of the time lag in firing, including reaction time of the gunner and lag in the firing mechanism.

e. Presentation and analysis of results: The results of all tests, firing from the stationary and moving tank and from the halt, at the several ranges and with the three different sights, are shown in the form of dispersion plots in Figs. 3 to 10 inclusive. The position of each hit with AP shot is indicated by horizontal and vertical coordinates over the 20' x 30' net. In the case of the ricochet HE, the center of effect of each burst on the ground is plotted for both range and deflection with reference to the target position and line of fire. On each graph the mean point of impact (MPI) is also shown.

(1) The dispersion patterns were, in each case, subjected to statistical analysis, the horizontal and vertical distributions being treated separately on the assumption (borne out by examination of the data) that the elevation and traverse controls operate independently of each other in determining the overall pattern. The calculations included determination of the mean point of impact (MPI), the standard deviations of the horizontal (σ_X) and vertical (σ_Y) dispersions and the area including 50% and 90% probability of hits.* The last two are determined directly from σ_X and σ_Y as $4.4\sigma_X \cdot \sigma_Y$ and $16.0\sigma_X \cdot \sigma_Y$ respectively. The use of these statistical parameters of the normal probability curve is justified in view of the good agreement between the observed dispersions and the normal distribution, as demonstrated by the representative case in Fig. 11. The resulting values are tabulated in Tables 1 to 7 inclusive, together with the number of rounds fired and the number of actual hits on the target. From these tabulated data one may determine the

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* The 50% area on a vertical target is comparable in significance to the distance of two probable errors in range, as commonly employed in artillery evaluation, in that there are equal chances that a hit will occur within or outside this area. It is the product of the horizontal and vertical distances about the mean point of impact which include 70.7% of hits in each direction (0.707 x 0.707 = 0.500).

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relative effectiveness of fire under the several conditions of operation.

3. RESULTS:

a. Stationary fire: The known high accuracy of stationary fire is demonstrated by the results of the present tests, as shown in Figs. 3,4 and 5, and in Table 1. The angular dispersion was roughly constant without regard to range, the standard deviations being 0.22 mils both horizontally and vertically. This leads to a 90% probability of hits* over an area considerably smaller than a tank silhouette. Even at a range of 1500 yds. the area of 90% probability is only 28 square ft. as compared with 49 square ft. for the tank front target.

b. Moving fire:

(1) The comparative performance of moving fire with the gyrostabilizer in operation was strikingly different, as shown in Figs. 7,8 and 9 and in Table 2. In terms of standard deviations, the horizontal and vertical dispersions were increased 7.5 to 17.5 times over those for stationary fire with corresponding decrease in effectiveness. Thus, the area of the 90% probability of hits at 200 yds. is 69 square ft. or 40% greater than a tank front (7'x 7'); at 500 yds. the 90% area increases to 193 sq. ft. or 4 times the area of the tank target, and at 1000 yds., the area of 90% probability is over eleven times greater. In terms of angular dispersion, there was a consistent decrease with range, as illustrated in Fig. 12. This is to be expected in view of the relative decrease in target size at the longer ranges, with consequent increase in the care with which the gunner selects his aim. The performance when firing from the moving tank traveling 20° to the left of the line of fire did not differ significantly from the results obtained when moving directly toward the target**. Although the differencies between sights were not highly significant; the best performance was given by the 6 power T8 periscopic sight.***

(2) The relative effectiveness of moving fire with stabilizer,(compared with the practical certainty of stationary fire) is well expressed in terms of the probabilities of hits on a tank front target. According to present tests, these are 82%,46% and 19% at 200, 500 and 1000 yards respectively (see Table 5 and Fig. 13). Thus, to obtain the same probability of hits on the target as in stationary fire it would be necessary to fire 1.2, 2.2 and 5.3 times as many rounds. With stationary fire, however, it is possible to aim at selected areas within the target which are relatively the most

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* All statements in this report in regard to probability of hits are based upon the range being known.

** Angle fire was investigated because it was felt that it might improve traverse control, owing to the need for constant adjustment of the deflection in one direction.

*** The nature of these tests does not permit a complete evaluation of the T8 sight in terms of its most important characteristics since questions of relative ease of target identification and use in failing light against camouflaged targets, etc., were not involved.

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TABLE 1

Dispersion of Hits in Stationary Fire

75mm Gun - AP Shot

SIGHT	No. Rounds		Dispersion					
	Fired	Hit Target	σ_x		σ_y		50% Area, ft.^{2}	90% Area, ft.^{2}
			ft.	mil	ft.	mil		
RANGE - 500 YARDS								
M4	5	5	.31		.37		0.50	1.84
M70	5	5	.39		.15		0.25	0.94
T8	5	5	.22		.20		0.19	0.70
	Aver.		.31	.21	.257	.17	0.35	1.30
RANGE - 1000 YARDS								
M4	10	10	.26		.60		0.69	2.50
M70	11	11	.87		.47		1.69	6.55
T8	10	10	.26		.27		.30	1.12
	Aver.		.54	.18	.47	.156	0.88	3.39
RANGE - 1500 YARDS								
M4	15	15	1.00		1.65		7.3	26.4
M70	15	15	1.42		1.47		9.3	33.7
T8	13	13	1.05		1.43		6.6	24.0
	Aver.		1.25	.28	1.53	.34	7.8	28.3
Aver. of All Ranges				.227		.220		

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TABLE 2

Dispersion of Hits in Moving Fire with Gyrostabilizer

75mm Gun - AP Shot

Angle of Travel	Sight	No. of Rounds			MPI from Target Center, ft.		Dispersion					
							σ_x		σ_y		50% Area sq. ft.	90% Area sq. ft.
		Fired	On Net	Hit Target	Horiz.	Vert.	ft.	Mil	ft.	Mil		
MEAN RANGE - 200 YARDS												
0°	M4	20	20	13	- .6	+1.3	2.3	3.84	1.9	3.17	20.0	69.0
MEAN RANGE - 500 YARDS												
0°	M4	40	40	18	-1.6	+1.5	4.3		3.3		63.6	226.0
20° Left	M4	40	38	14	- .5	-1.7	4.85		2.85		62.4	221.0
0°	M70	40	36	10	- .5	+ .5	3.62		4.00		65.6	232.0
20° Left	M70	20	20	11	- .7	+ .1	3.58		2.20		35.7	126.0
0°	T8	40	37	18	- .8	-1.0	4.30		3.83		74.5	263.0
20° Left	T8	15	15	9	-2.0	-1.0	2.86		2.15		28.1	98.0
	Aver.	215		93			3.97	2.65	3.14	2.1	55.5	193.0
MEAN RANGE - 1000 YARDS												
0°	M4	40	37	5	+3.0	+2.5	9.7		5.4		235.0	837.0
20° Left	M4	20	17	3	-1.3	-0.5	7.34		5.24		173.0	611.0
0°	M70	16	16	4	+1.2	+1.7	6.92		5.35		167.0	592.0
20° Left	M70	20	19	6	-0.1	+1.8	6.56		3.78		111.0	395.0
0°	T8	41	35	9	-0.5	+0.8	6.00		4.85		130.0	465.0
20° Left	T8	40	37	6	+0.5	+4.0	7.10		4.70		150.0	535.0
	Aver.	177		33			7.36	2.45	4.92	1.64	163.0	560.0

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vulnerable, whereas the above probabilities for moving fire are based upon securing a hit anywhere upon the target. Even with equal numbers of hits on the target, therefore, moving fire must be considered less effective and the ratios of ammunition requirements to accomplish the desired task (immobilization or destruction of enemy tank) must be increased over those given above.

(3) The improvement in gun stability afforded by the gyrostabilizer is shown by the comparative results in Fig. 9 and Table 3. The horizontal dispersion of fire is found to be the same with or without the stabilizer but the vertical spread is substantially reduced by the equipment. Thus, the vertical standard deviation without the gyrostabilizer is approximately 1.5 times greater with corresponding decrease in probability of hits. At 200 yards, the chances of hitting the tank front target is reduced without the stabilizer by approximately one half; at 500 yards, by 60% and at 1000 yards by approximately two thirds (estimated).

c. Firing from halt. In view of the considerable loss of precision in moving fire, the results obtained in firing from the halt are of practical interest (see Figs. 3,4,5 and 6 and Table 4). The dispersion is greater than in true stationary fire, but markedly less than with moving fire. Angular dispersion decreased with distance, the horizontal and vertical standard deviations ranging from 0.75 mils and 0.90 mils at 500 yards to approximately 0.40 mils in both directions at 1500 yards. Thus, the dispersions were increased two to four times over stationary fire. Probabilities of hits on the tank front target, however, remained high and were of the order of 99+%,99+% and 88% at 200,500 and 1000 yards respectively (See Table 5 and Fig.13). Even at 2000 yards the probability of hit on the tank front target was 66 to 80%, which is roughly equivalent to the chances of a hit at 200 yards with moving fire. Of greater significance, perhaps, is the relatively higher rate of effective fire, i.e., actual hits per minute. Moving at an approximate rate of 10 mph through the firing zone, it required on the average, 45 seconds and 69 seconds respectively to travel through the 200 yard and 300 yard zones for the 500 yard and 1000 yard ranges. During these trips the number of rounds fired averaged 4 with the M70, 5 with the M4 and 6 with the T8 sights. From these figures and the percentages of hits on the tank front target, the number of hits per minute was calculated. The total time of passage through the zone and the halted time were recorded during the tests of firing from the halt. Since the number of rounds fired during each trip was kept constant at 4,5 or 6 for the respective sights, it was possible to calculate, similarly, the number of hits per minute when firing from the halt. The resulting data are presented in Table 6 and Fig. 14. In terms of overall time of passage through the zone, one notes that the effective rate of fire was generally more than twice as high when firing from the halt than from the moving tank and that at ranges of 1500 and 2000 yards, the number of hits per minute was nearly as great as at 500 yards with moving fire.* In terms of halted time only, the difference is many times greater with the result that more effective fire can be maintained from the halt at 2000 yards than

* Owing to the soft ground, tank speed was limited. This increased time of passage through the zone and thus decreased the rate of effective fire (hits per minute) in the technic of firing from the halt.

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TABLE 3

Comparative Dispersions of Hits in Moving Fire - With and without Gyrostabilizer

75mm Gun - AP Shot

Gyro	Sight	No. of Rounds			MPI From Target Center, ft.		Dispersion					
							σ_x		σ_y		50% Area sq. ft.	90% Area sq. ft.
		Fired	On Net	Hit Target	Horiz.	Vert.	ft.	Mil	ft.	Mil		
MEAN RANGE - 200 YARDS												
With	M4	20	20	13	- .6	+1.3	2.3	3.84	1.9	3.17	19.0	70.0
Without	M4	20	20	8	-2.0	+0.8	2.33	3.88	4.8	8.0	49.0	180.0
With	M4	40	40	18	-1.6	+1.5	4.3	2.86	3.3	2.2	62.6	226.0
Without	M4	20	15	5	+1.2	+2.9	4.2	2.80	9.0*	6.0*	166.0	600.0

* Obtained graphically from plot on probability paper, in absence of exact information on position of 5 misses.

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TABLE 4

Dispersion of Hits in Firing from Halt

75mm Gun - AP Shot

Sight	No. of Rounds			MPI from Target Center, ft.		Dispersion					
						σ_x		σ_y		50% Area sq.ft.	90% Area sq.ft.
	Fired	On Net	Hit Target	Horiz.	Vert.	ft.	Mil	ft.	Mil		
RANGE - 500 YARDS											
M4	20	20	20	+ .3	- .3	1.23		1.34		4.2	14.3
M70	18	18	18	- .5	-1.4	1.14		1.36		7.0	25.0
T8	20	20	20	+ .7	-1.8	1.00		1.29		6.4	23.3
	Aver.					1.13	.75	1.33	0.9	5.87	20.87
RANGE - 1000 YARDS											
M4	20	20	18	+ .7	-1.8	1.00		1.29		5.5	20.0
M70	20	20	19	- .4	- .7	2.12		1.41		13.2	47.0
T8	24	24	24	- .4	- .4	1.90		1.73		14.4	49.0
	Aver.					1.78	.59	1.49	.50	11.03	38.66
RANGE - 1500 YARDS											
M4	20	20	12	+2.5	-1.2	2.43		1.87		20.2	73.1
M70	20	20	16	0	- .5	2.41		1.79		18.0	67.2
T8	24	24	20	- .2	- .5	1.87		1.45		11.7	42.3
	Aver.					2.26	.50	1.72	.38		
RANGE - 2000 YARDS											
M70	20	17	13	+1.4	-1.2	2.8*		2.6*		69.1	258.0
T8	20	20	16	0	+1.3	2.0*		2.5*		40.0	153.0
	Aver.					2.4	0.40	2.55	0.42	54.5	205.5

*Obtained graphically from plot on probability paper because of positions of extreme hits.

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TABLE 5

COMPARATIVE PROBABILITIES OF HITS

Stationary Fire, Firing From Halt, Moving Fire With and Without Gyrostabilizer

TYPE FIRE	Probability of Hit on Tank Front* at Stated Ranges		
	200 Yds.	500 Yds.	1000 Yds.
Stationary	99+ %	99+ %	99+ %
From Halt	99+ %	99+	88%
Moving, with Gyro	82%	46%	19%
Moving, without Gyro	46%	18%	6.5%(est)

* Taken to be 7 ft. x 7 ft.

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TABLE 6

Comparative Rates of Fire and Hits per Minute
Moving Fire with Gyrostabilizer and
Firing from Halt

RANGE	SIGHT	RDS. PER MINUTE			HITS PER MINUTE		
		Moving	From Halt		Moving	From Halt	
			Total	Halted		Total	Halted
500 yd	M4	5.7	5.5	19.0	2.28	5.5	19.0
"	M70	5.3	4.3	17.0	1.85	4.3	17.0
"	T8	8.0	6.0	26.0	3.93	6.0	20.0
1000 yd	M4	4.26	3.7	14.5	0.57	3.3	13.0
"	M70	3.90	3.1	11.1	1.08	2.9	10.5
"	T8	5.02	4.1	14.0	0.93	4.1	14.0
1500 yd	M4	-	2.5	9.7	-	1.5	5.8
"	M70	-	2.2	9.7	-	1.8	7.8
"	T8	-	2.8	9.6	-	2.3	8.0
2000 yd	M4	-	-	-	-	-	-
"	M70	-	2.2	4.0	-	1.4	2.6
"	T8	-	3.7	8.1	-	2.9	6.5

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at 500 yards from the moving vehicle. This substantial gain in effective fire is accomplished without significant, if indeed any, cost in terms of vulnerability since the time of passage through the zone is increased only 25%. Firing from the halt appears also to lend itself more suitably to evasive action with consequent decrease in vulnerability.

d. Comparative results with ricochet burst HE: The results of tests of moving fire and firing from the halt are shown graphically in Fig. 10 and summarized in Table 7. With the M4 sight, the dispersion in range was in good agreement with that anticipated from the vertical dispersion obtained with AP fire. The standard deviation in the latter case was 2.1 mils which, when converted into range for M48 HE (70 yards per mil at 500 yards.) amounts to 147 yards, as compared with 130 yards, actually obtained with HE fire. In the case of the M70 and T8 sights, however, the dispersion in range was considerably better than expected from the AP results. With all three sights the deflection dispersion was approximately equal to that obtained with AP fire, the high majority of burst centers being within 10 ft. of the line of fire. The probability of securing an effective hit on a horizontal target, was low. This results in part from the fact that the center of the burst has to be immediately adjacent to the target area to produce damage and emphasizes the need for high accuracy of fire against a selected horizontal or dug-in target which is not attainable with moving fire. Taking as a minimum criterion, the ability to place bursts within ± 15 yards of a selected mean point of impact to secure effect, the probabilities in moving fire are 10, 20 and 26% with the M4, M70 and T8 sights, respectively. When firing from the halt, the probabilities were increased in these tests to 55% and 32% for the M70 and T8 sights.

e. Stability of gun in moving tank: The angular travel of the gun in relation to the target, as recorded for representative periods of 3 to 5 seconds just prior to shooting on the 1000 yard range, is shown in Figs. 15a to 15f. Separate curves are presented for horizontal and vertical movement. They are plotted with constant time and angle scales so that the velocity of travel at any point may be readily determined as the slope of the tangent of the curve. The curves show a marked variability in magnitude and velocity of travel and a complete lack of cyclical regularity and there appears to be no relation between the period or amplitude of the horizontal and vertical movements. The action of the gyrostabilizer in improving vertical stability is demonstrated by the greater regularity and considerably less amplitude in the elevation curves. It is clear, however, that full advantage cannot be taken of this relative stability because of the highly erratic behavior of the horizontal movement. For effective shooting on the move it is evident that three favorable conditions must occur simultaneously; the angular velocity of the gun must be zero or at a constant minimum rate in both directions and it must course across the target at the instant of firing. In only two of the 12 instances illustrated was the gunner able to select a favorable condition with respect to the angular velocities. It is not known whether or not the gun was so adjusted as to pass the target center simultaneously in these two cases. In all other instances there was considerable angular velocity in one or both directions.

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TABLE 7

Comparative Dispersions - Ricochet HE

Moving Fire with Gyrostabilizer vs Firing from Halt

Range - 500 Yds.

TYPE FIRE	SIGHT	No. Rounds		MPI, yds Range	Range Dispersion, yds.			Probability of burst within ±15 yds of MPI, %
		Fired	Damage Target		σ_y	50% Range	90% Range	
Moving	M4	40	2	+30	130	176	420	10
Moving	M70	20	0	+13	62	84	202	20
From Halt	M70	20	4	0	13	17	42	55
Moving	T8(6x)	20	0	-20	47	64	150	26
From Halt	T8(6x)	20	4	+20	31	42	100	32

Chart #1

f. Time lag in firing: Because of the wide variability in velocity and magnitude of travel of the gun and complete lack of similarity between the two curves, it becomes obvious that the time lag between the instant when the gunner decides to shoot and the time of actual firing is an important factor in determining the accuracy of moving fire. Accordingly, approximate measurements of this time lag were made on the gunner and the tank employed in these tests. Technic of measurement was as follows:

The gunner was seated in the stationary tank and followed through the sight a lamp bulb 100 ft. distant which was moved about a zone to approximate the magnitude and velocity of movement of the actual target in the field. He kept the gun on this target by means of the hand elevation wheel and power traverse. His signal to fire was the turning on or off of the lamp. This signal started an electric timer which was stopped when the firing pin struck the shell casing, the elapsed time representing the total time lag. In order to eliminate the learning factor the observations were carried out repeatedly during an afternoon and the following morning and afternoon. The overall improvement from one afternoon to the next was not significant. The increase over simple reaction time caused by tracking the target was found as the difference between the total time, as measured above, and the time required to complete the action when the gunner simply watched for the signal without simultaneous tracking. The mechanical time lag in the firing button and in the solenoid and following mechanical linkage were similarly measured, using appropriate electrical contact switches to mark the beginning and end of the period. The average results from twenty or more measurements for each element are given in Table 8. The total time lag is seen to be approximately one-half second. Because of the artificial nature of the experimental technic this is believed to be a minimum figure. It does not allow, for example, for the disturbance to the gunner in the moving vehicle with consequent necessity for him to keep his eye in the sight and at the same time operate the controls. As an approximate measure, it may be applied to the curves of gun movement, in Figs. 15a to 15f, thus making possible a comparison between the stability of the gun at the instant when the gunner decided to fire and the actual time of firing. The comparative velocities and the degree of gun travel during the one-half second lag period are shown on each curve. Several significant points emerge from study of these curves. It is evident that the stability of the gun as measured by angular velocities was no better at the earlier period. Of greater importance, the distance the gun moved during the lag period varied widely and in a wholly unpredictable manner. This observation is important in view of the statement in the Technical Manual 9-731A that in moving fire the gunner learns to anticipate gun movement and is thus prepared to fire the instant the line of sight comes through the target. From a study of these records one must conclude that this alleged practice is not practical owing to the unpredictable speed of angular travel of the gun. As a matter of fact, careful questioning of the gunner revealed that he simply fired when the target was properly lined up in the sight without regard to the stability of the gun at that moment and with no allowance for time lag. The correctness of aim then, was a matter of chance and, according to the records illustrated here, there is a 50-50 probability of the error being

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TABLE 8

Time Lag in Firing

ELEMENT	TIME - SECONDS	
	Aver.	90% Range
Simple Reaction Time	0.285	0.24 to 0.34
Reaction Time with Tracking	0.407	0.30 to 0.48
Lag in Firing Mechanism	0.104*	0.095 to 0.130
Total Time Lag	0.511	0.44 to 0.60

* Foot button - 0.042; solenoid and mechanical linkage= 0.062

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within or outside an area of 2.92 x 4.50 mils. Converted to area in square feet at 1000 yards, this equals 119 square feet which may be compared with an average area of 163 square feet for 50% probability of actual hits at 1000 yards, as shown in Table 2. The relative magnitude of these values suggests that a major portion of the error in moving fire with present limited stabilization, which exists in spite of the selection by the gunner of relatively favorable moments for firing, arises from the inherent time lag involved in the process. Reference to Table 8 shows that 80% of this elapsed time is chargeable to limitations in rapidity of action of the gunner and of this some 70% is basic reaction time. Improvement of controls might decrease the added reaction time resulting from tracking and better design of the firing mechanism would reduce its contribution. It is doubtful, however, if these would reduce the total by more than 25%.

g Comparative stability of gun in relation to terrain

It is recognized that the relative stability of the gun during tank movement is influenced by the roughness and irregularity of the ground over which the vehicle is travelling. Because of this, essentially flat terrain was selected for these tests in an effort to secure the most favorable conditions of operation. The degree to which this was achieved is demonstrated by comparing the records of angular movement of the gun during the firing tests (Figs 15 a to 15f), with similar curves (Figs. 16a to 16c) obtained while making a dry run over a prepared gravel surface roadway at Cedar Creek Range, Fort Knox, with the gunner tracking a target some 700 yards distant. The curves for Rolling Fork Range are seen to be smoother and more regular than those for the prepared roadway and demonstrate the somewhat superior ground characteristics on the area selected for the tests. It may be concluded, therefore, that the results here reported represent performance on highly favorable ground, a condition which will not ordinarily be encountered in combat areas.

4. SUMMARY OF RESULTS:

Insofar as the 75 mm gun is concerned, the results of these tests show that, even under the most favorable conditions, the relative precision of fire on the move decreases rapidly with range and that the cost, in terms of increased ammunition requirements to accomplish an effective result is high, especially in view of the limited amount of ammunition available in the vehicle. It is further demonstrated that this excessive cost is largely wasted in view of the evident lack of advantage gained over firing from halt. The superiority of effective fire with the latter technic is clearly shown and, at the same time, there is no evidence of increased vulnerability of the tank to enemy fire or marked decrease in the rate of advance. As a matter of fact, in neither case is it possible to show any real advantage from the standpoint of reduced vulnerability, since the speed of the moving tank was not great enough to effect seriously the precision of an opposing high velocity antitank gun. The limited precision of moving fire is inher-

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ent in the equipment and must remain so as long as limited stabilization is provided in elevation only. It is clear from the present study that even the degree of vertical stabilization which is now provided cannot be fully utilized so long as the gunner is required to control the highly erratic and rapid horizontal movement of the gun entirely by means of the power traverse. Furthermore, without a high degree of stabilization in both directions, the precision of fire is necessarily limited by the unavoidable time lag between the decision to fire and the instant when firing actually occurs.

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General View of Rolling Fork Range, Showing Area Employed in Tests

ARMORED MEDICAL RESEARCH LABORATORY

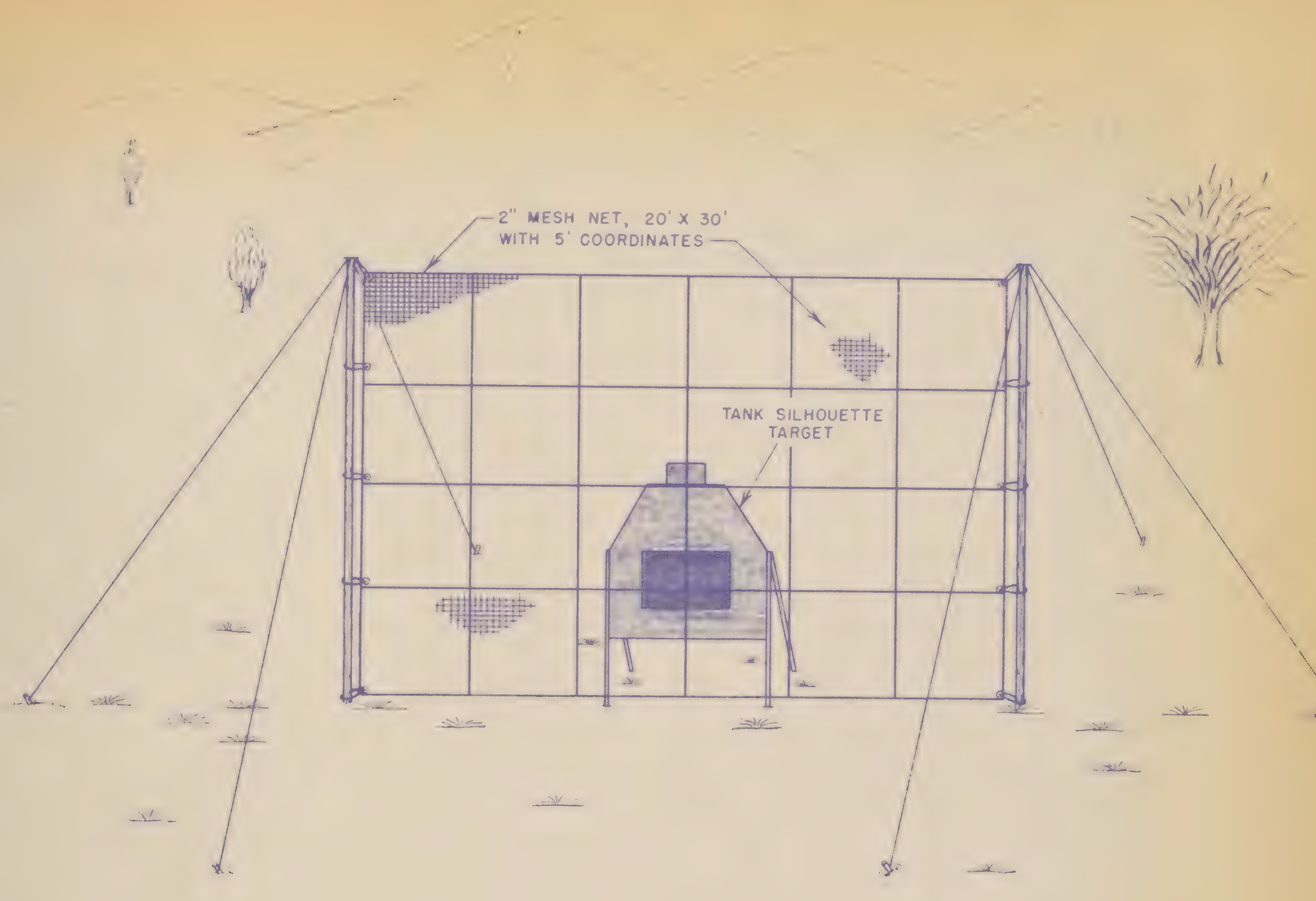
FORT KNOX, KY.

Project No. 21

Figure 1

[illegible]

[illegible]
[illegible] S. Army."



TANK FRONT SILHOUETTE TARGET AND 20' X 30' NET

FIG. 2

FIG. 2

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FIG. 3

OBSERVED DISPERSIONS, STATIONARY FIRE AND FIRING FROM HALT
M4A3 MED. TANK, 75 MM GUN, AP M72 AMMUNITION

RANGE – 500 YARDS

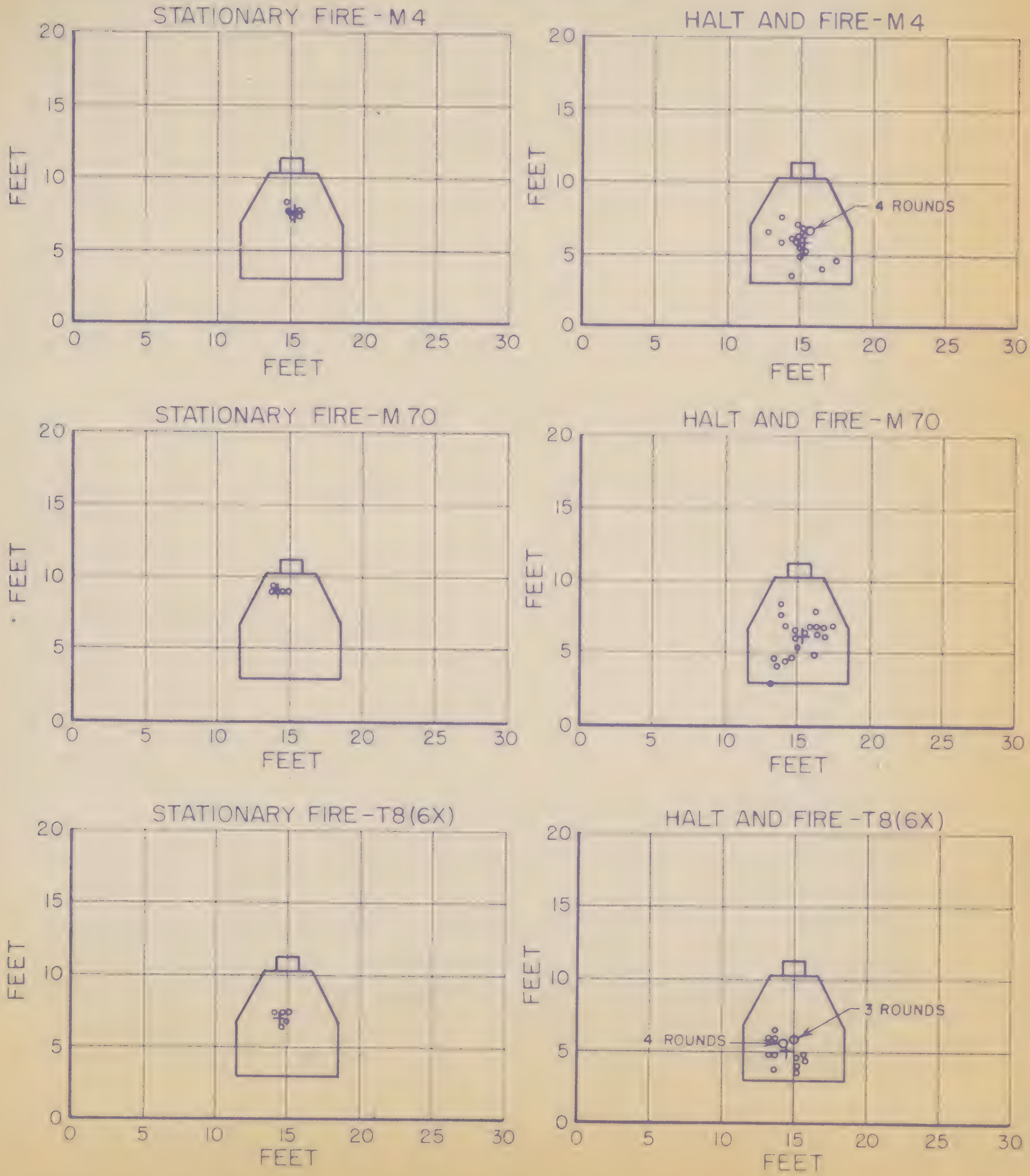

FIG. 3

FIG. 4

OBSERVED DISPERSIONS, STATIONARY FIRE AND FIRING FROM HALT
M4A3 MED. TANK, 75 MM GUN, AP M61 AMMUNITION

RANGE - 1000 YARDS

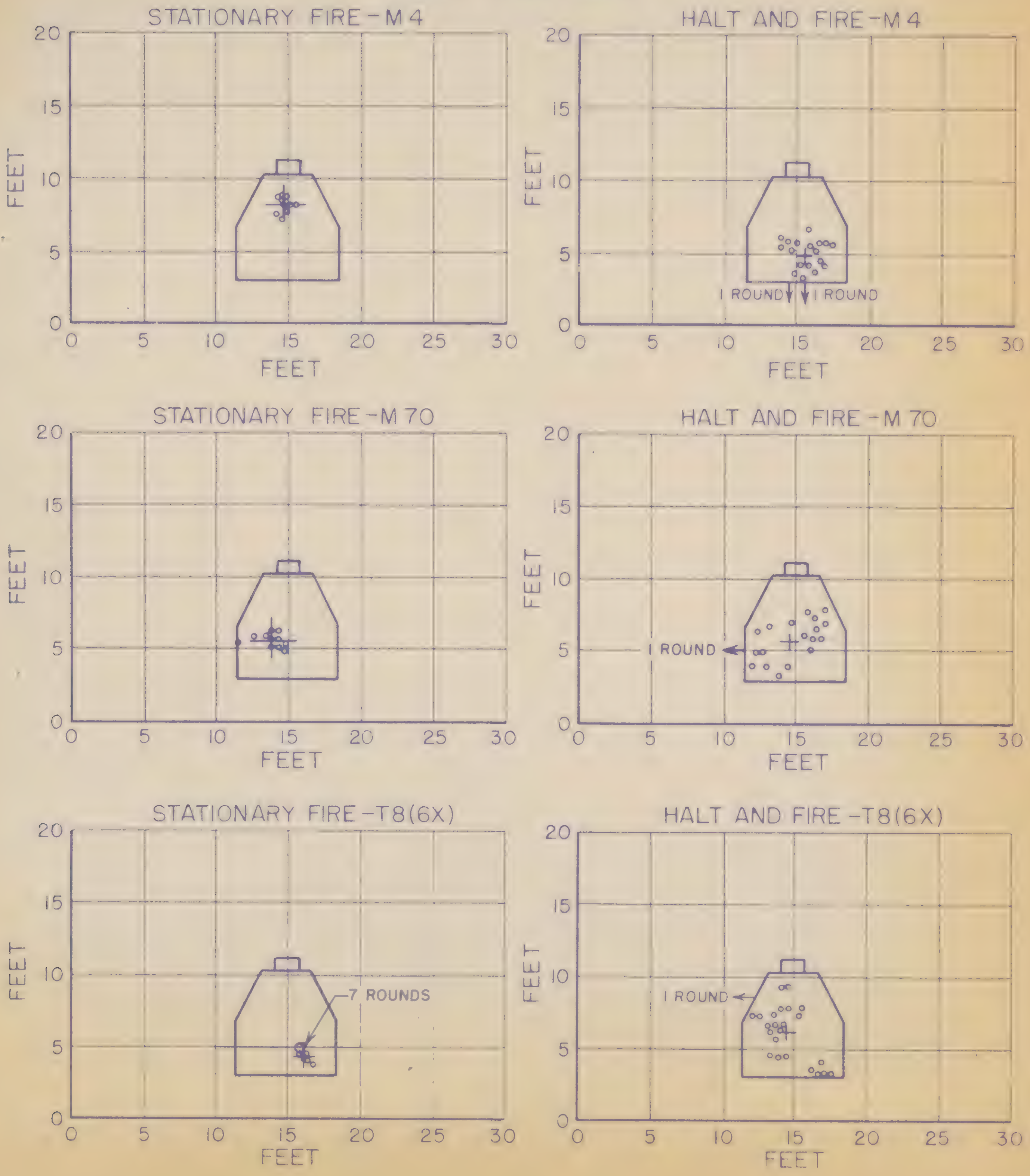

FIG. 4

FIG. 5

OBSERVED DISPERSIONS, STATIONARY FIRE AND FIRING FROM HALT
M4A3 MED. TANK, 75 MM GUN, AP M61 AMMUNITION
RANGE - 1500 YARDS

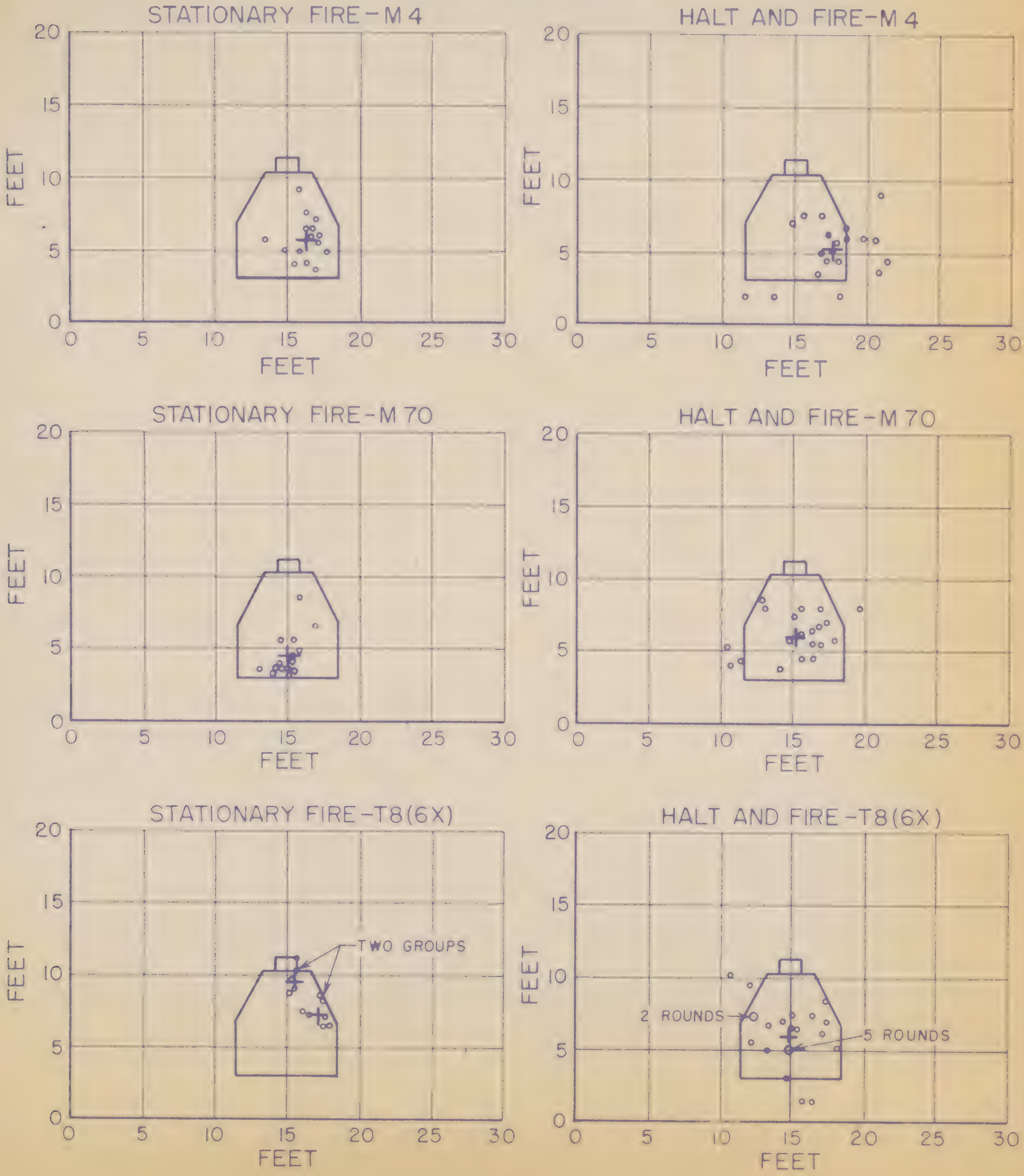

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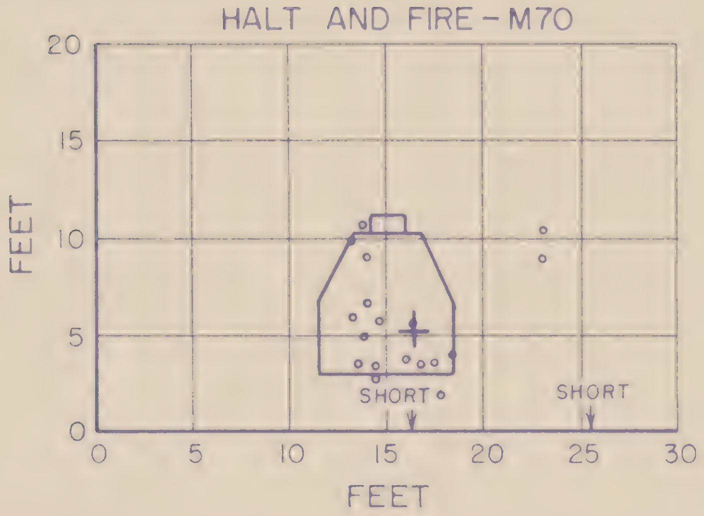
FIG. 5

FIG. 6

OBSERVED DISPERSIONS, FIRING FROM HALT

M4A3 MED. TANK, 75 MM GUN, AP M61 AMMUNITION

RANGE - 2000 YARDS



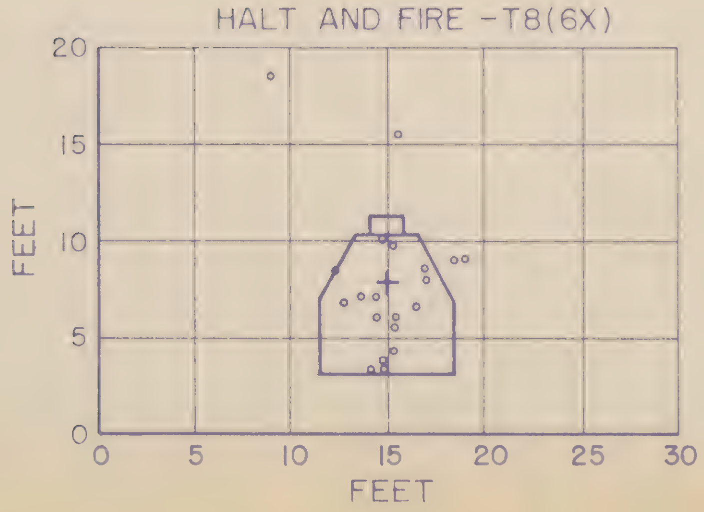


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FIG. 6

FIG. 7

OBSERVED DISPERSIONS, MOVING FIRE WITH STABILIZER
M4A3 MED. TANK, 75 MM GUN, AP M72 AMMUNITION

RANGE – 500 YARDS

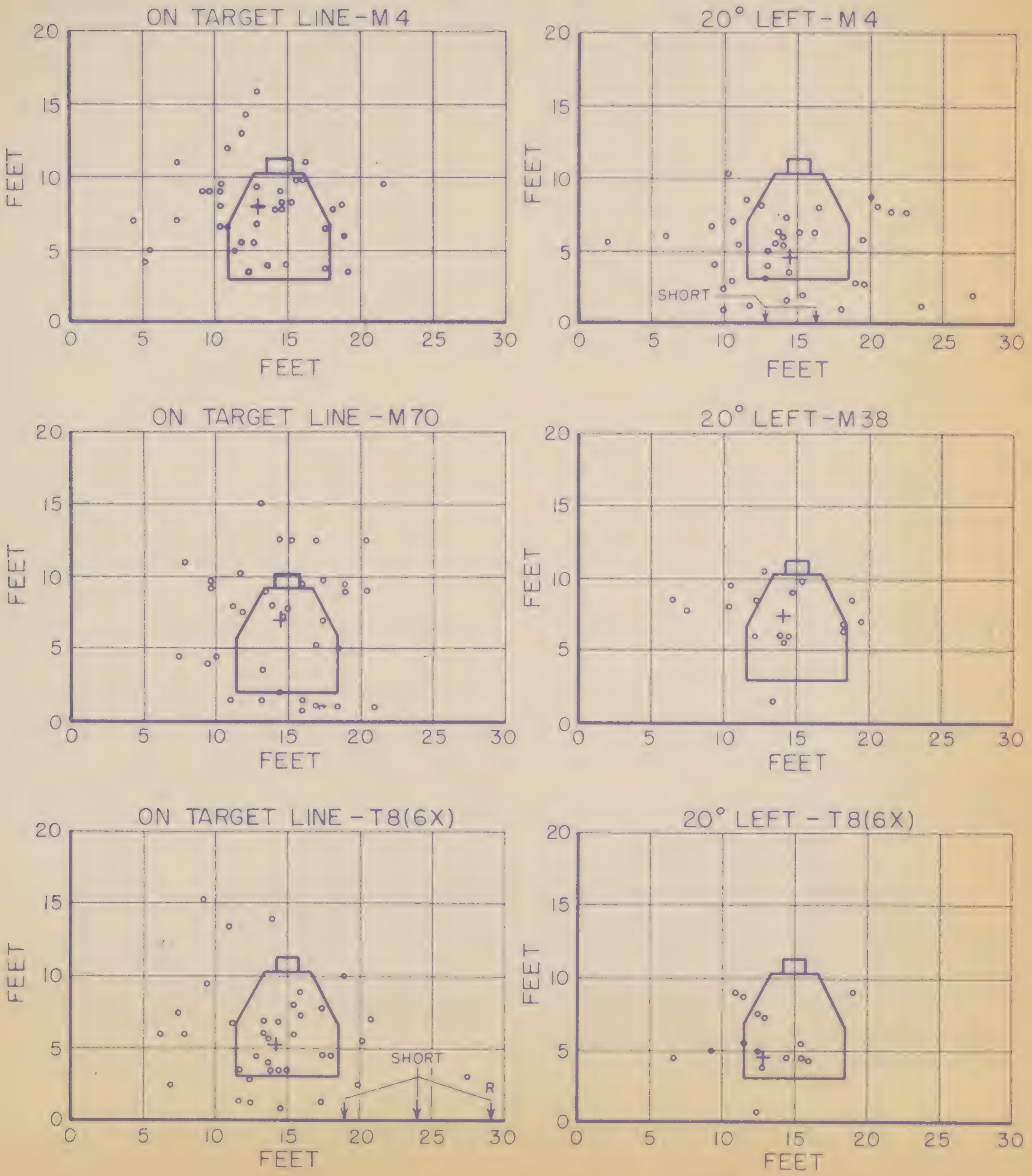

FIG. 7

FIG. 8

OBSERVED DISPERSIONS, MOVING FIRE WITH STABILIZER
M4A3 MED. TANK, 75 MM GUN, AP M61 AMMUNITION

RANGE - 1000 YARDS

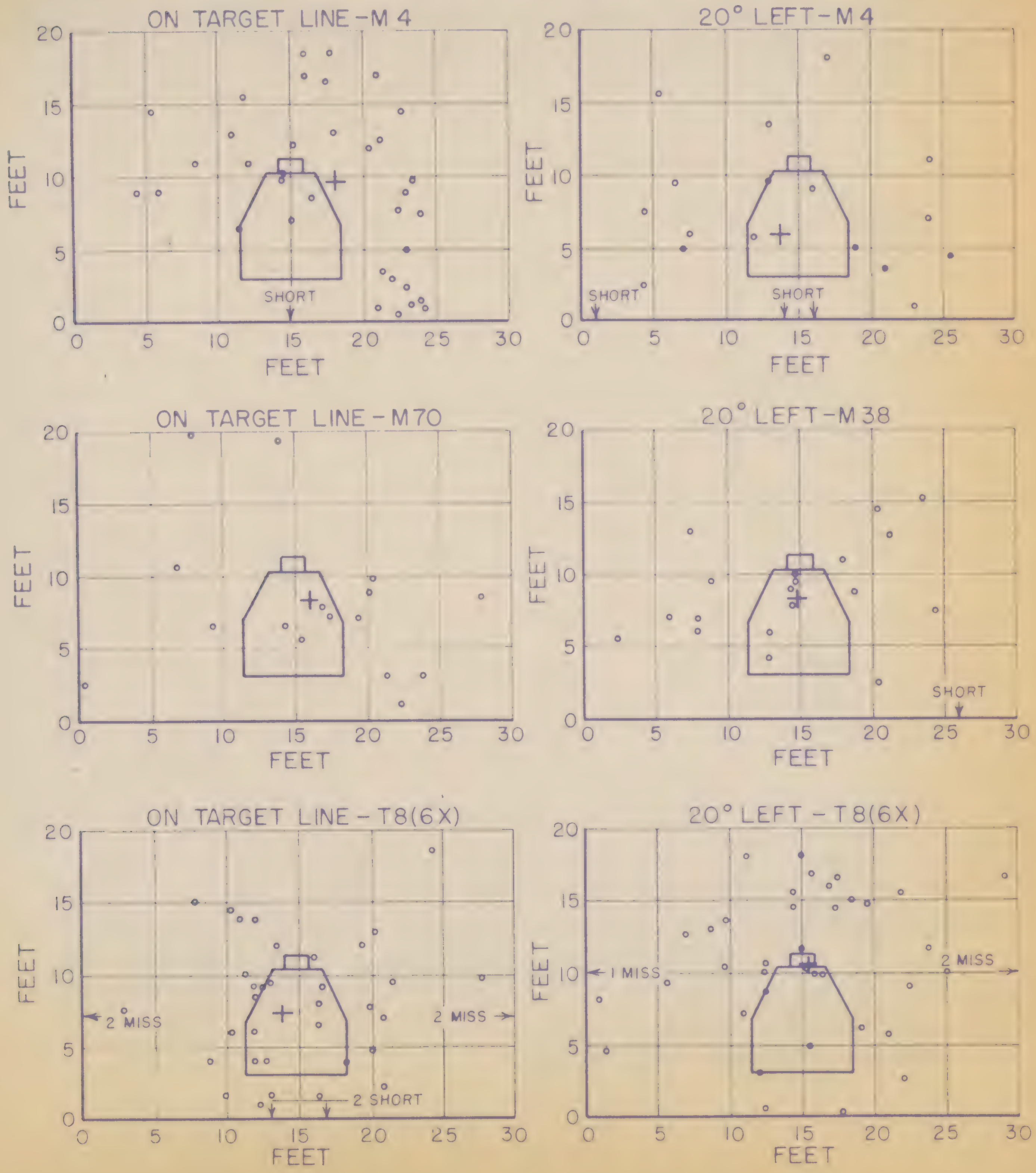

FIG. 8

FIG. 9

OBSERVED DISPERSIONS - MOVING FIRE WITH AND WITHOUT STABILIZER
M4A3 MED. TANK, 75MM GUN, (M-4 SIGHT) APM72 AMMUNITION

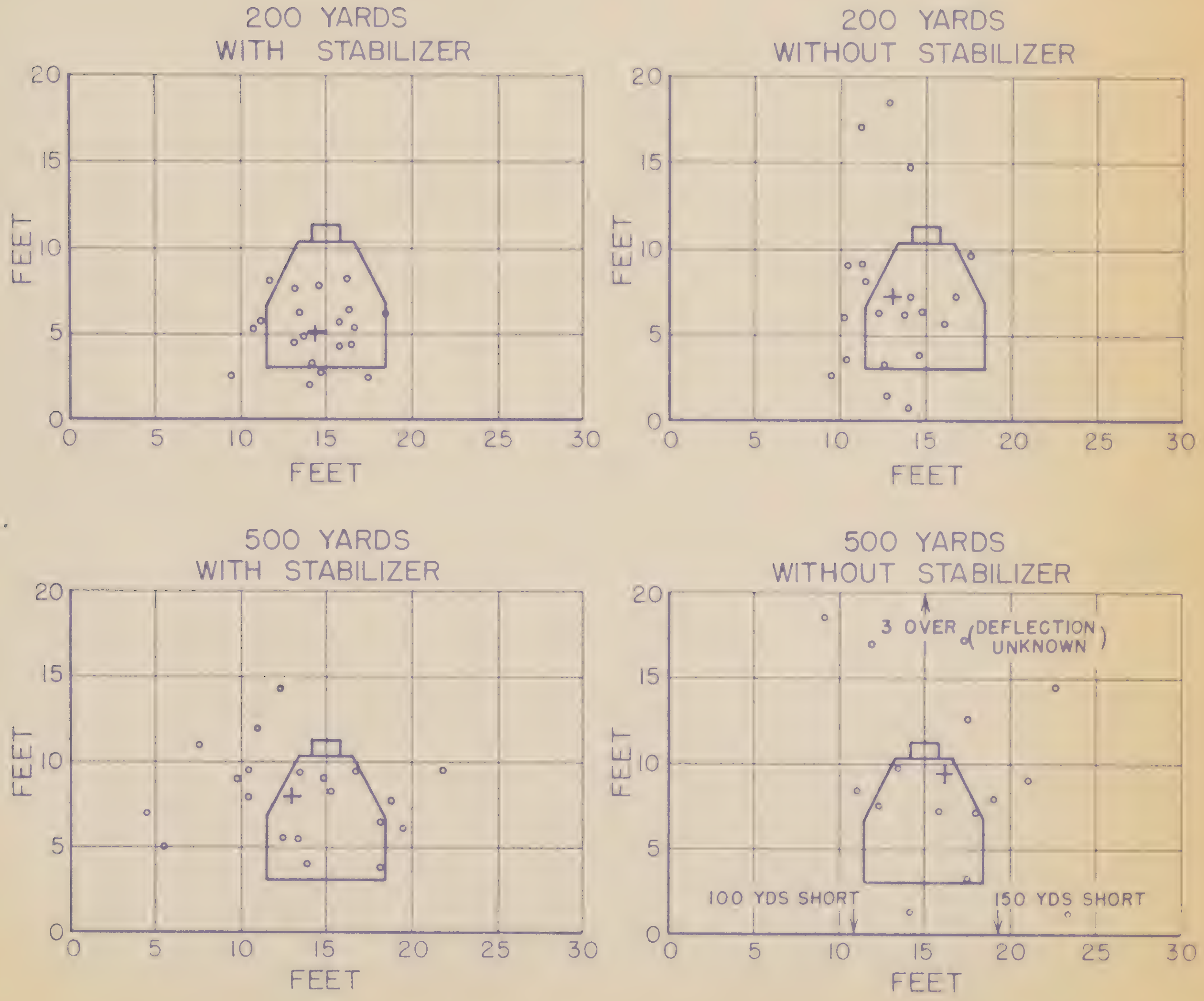

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FIG. 10

OBSERVED DISPERSIONS - HIGH EXPLOSIVE FIRE

MOVING FIRE WITH GYROSTABILIZER AND FIRING FROM HALT

RANGE-500 YARDS

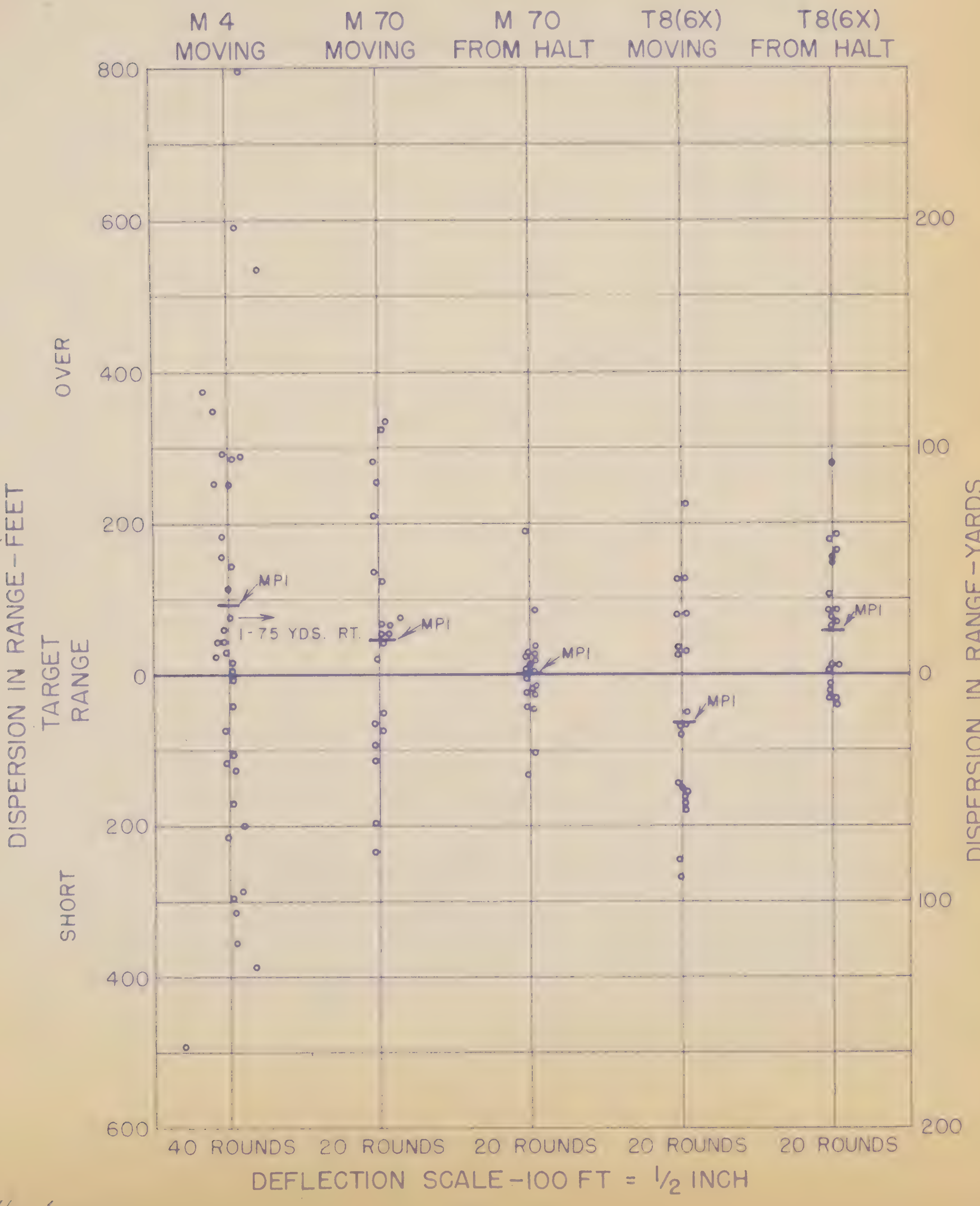

FIG. 10

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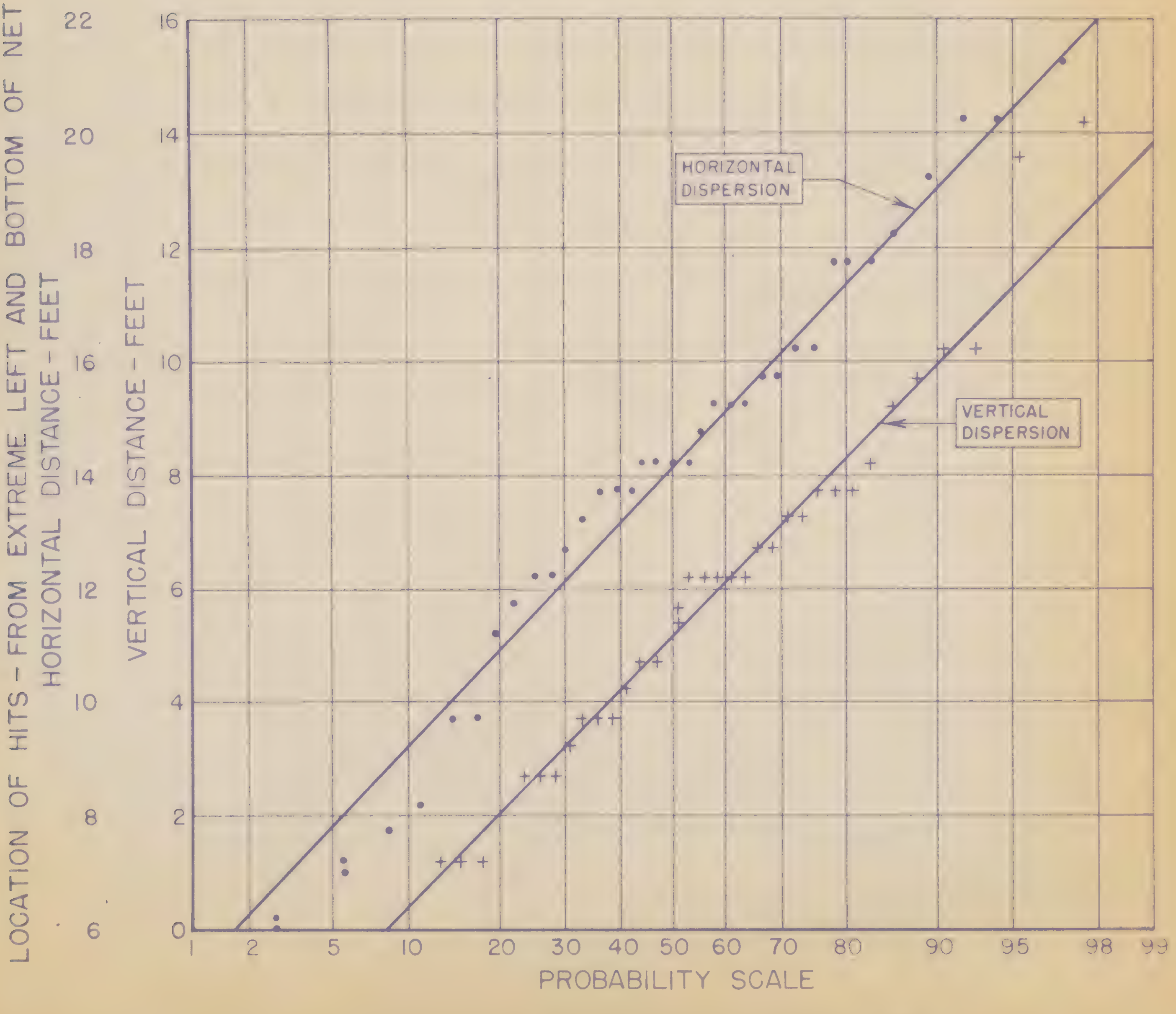
FIG. 11

HORIZONTAL AND VERTICAL DISPERSIONS
MOVING FIRE WITH GYROSTABILIZER

500 YARDS - T8 (6X) SIGHT

(STRAIGHT LINE EQUALS NORMAL PROBABILITY DISTRIBUTION)



PERCENT HITS ≧ STATED DISTANCE FROM
HORIZONTAL AND VERTICAL REFERENCE LINES

FIG. 11

FIG. 12

DISPERSION OF FIRE IN RELATION TO RANGE
COMPARISON OF STATIONARY FIRE, FIRING FROM HALT
AND MOVING FIRE WITH GYROSTABILIZER

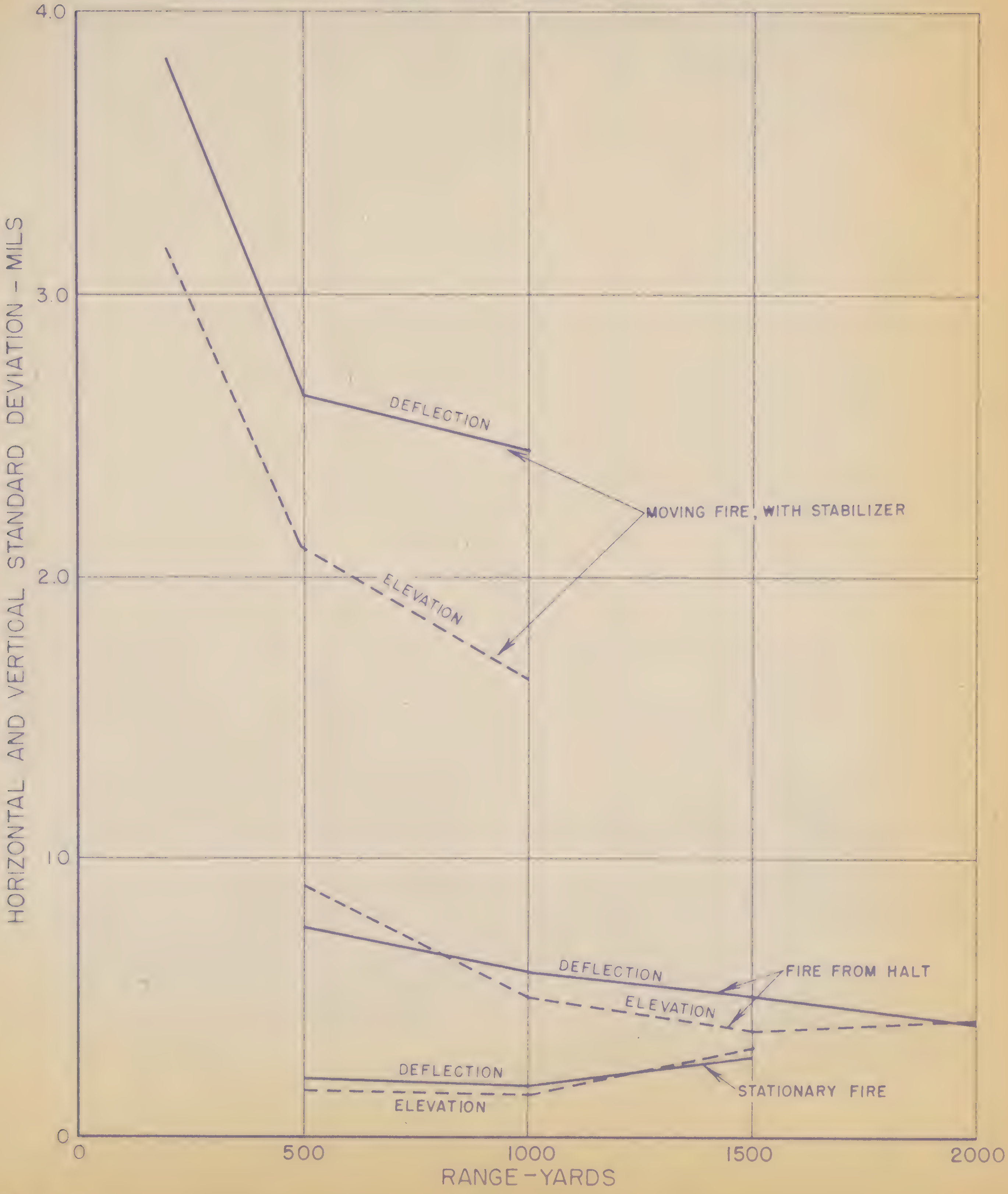


FIG. 12

FIG. 13

PROBABILITY OF HITS ON TANK FRONT TARGET IN RELATION TO RANGE
COMPARISON OF STATIONARY FIRE, FIRING FROM HALT
AND MOVING FIRE WITH AND WITHOUT GYROSTABILIZER
75 MM GUN, AP SHOT

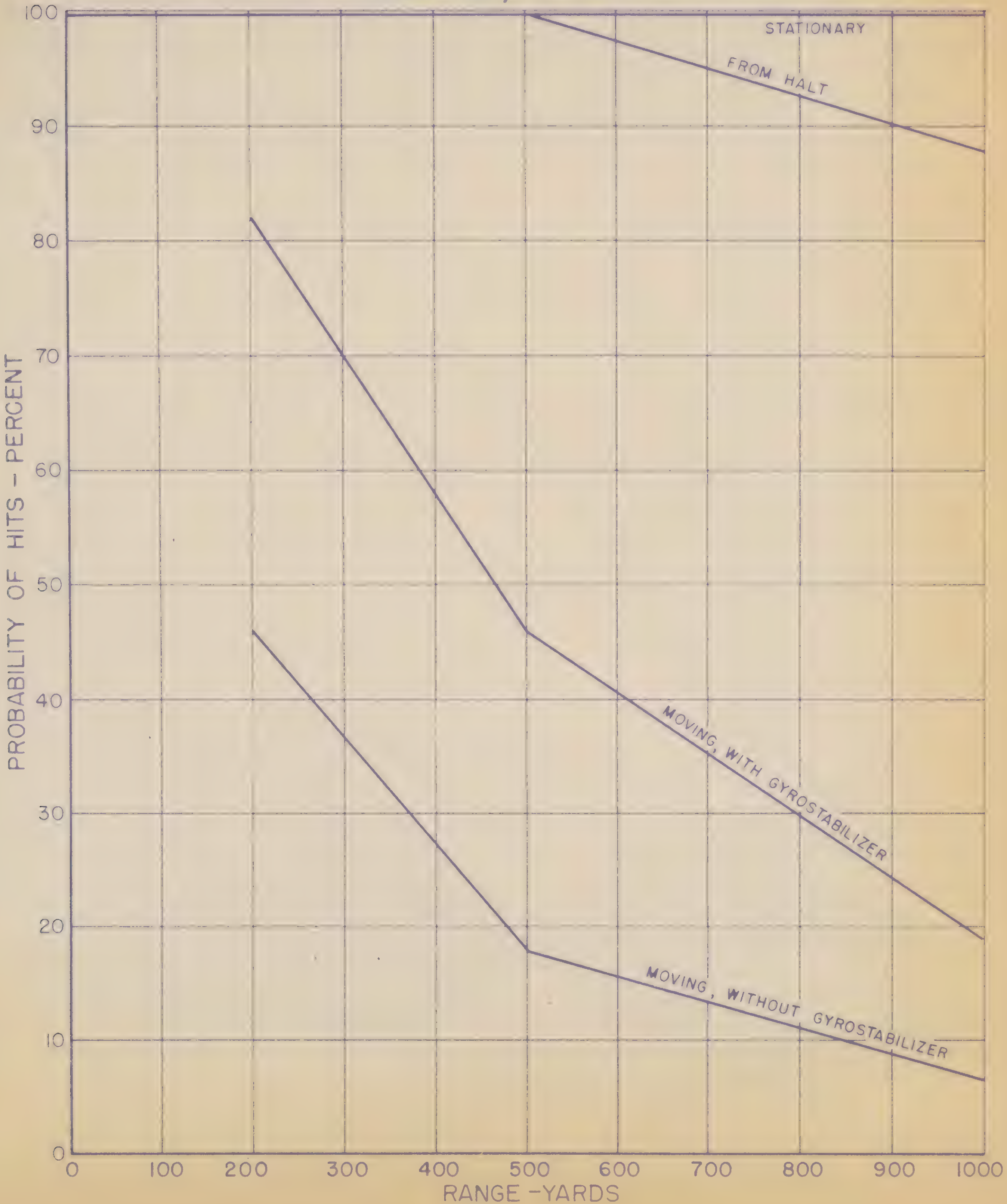


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FIG. 13

FIG. 14

EFFECTIVE RATE OF FIRE IN RELATION TO RANGE
COMPARISON OF FIRING FROM HALT AND MOVING FIRE WITH STABILIZER
75 MM GUN, AP SHOT

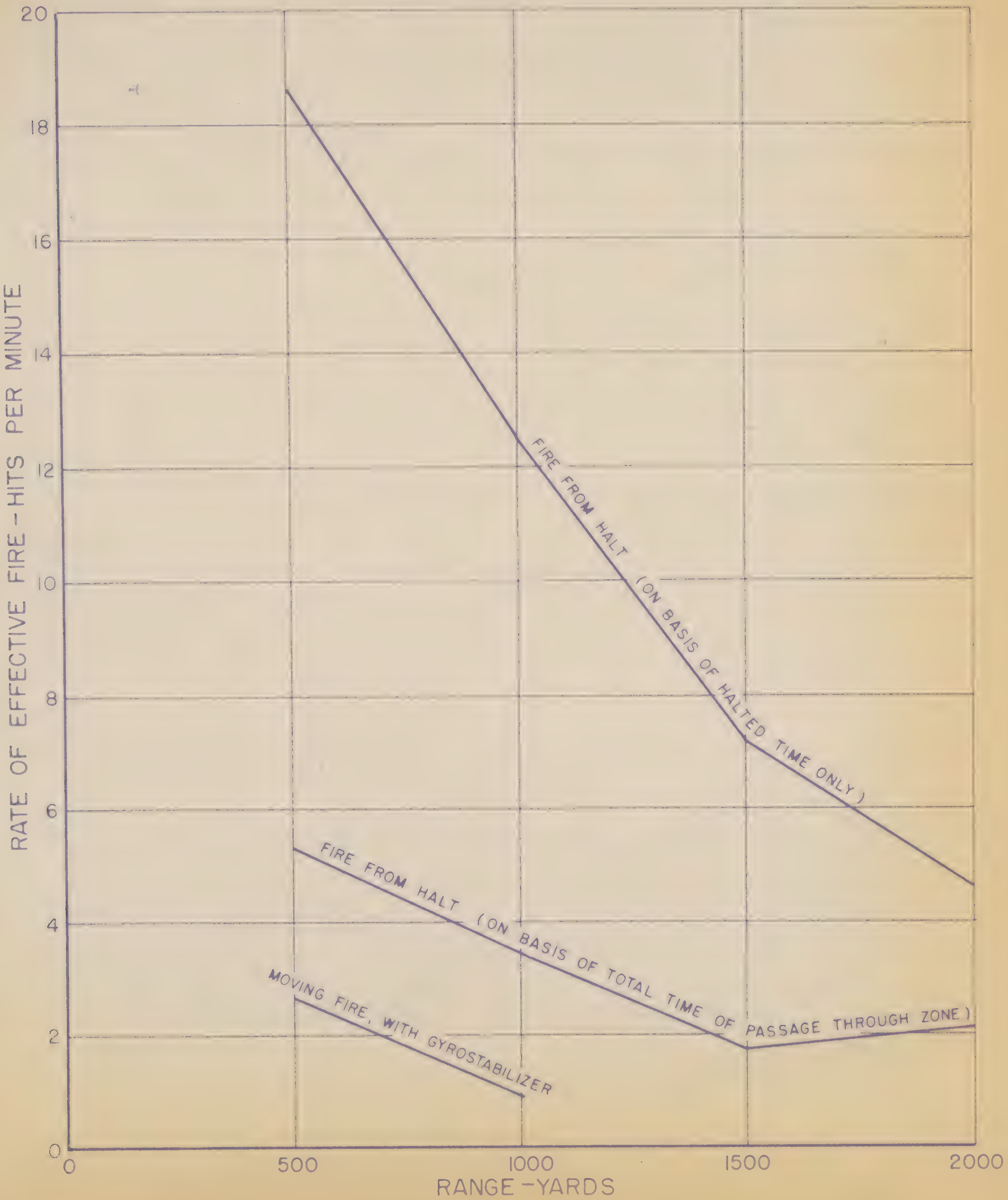

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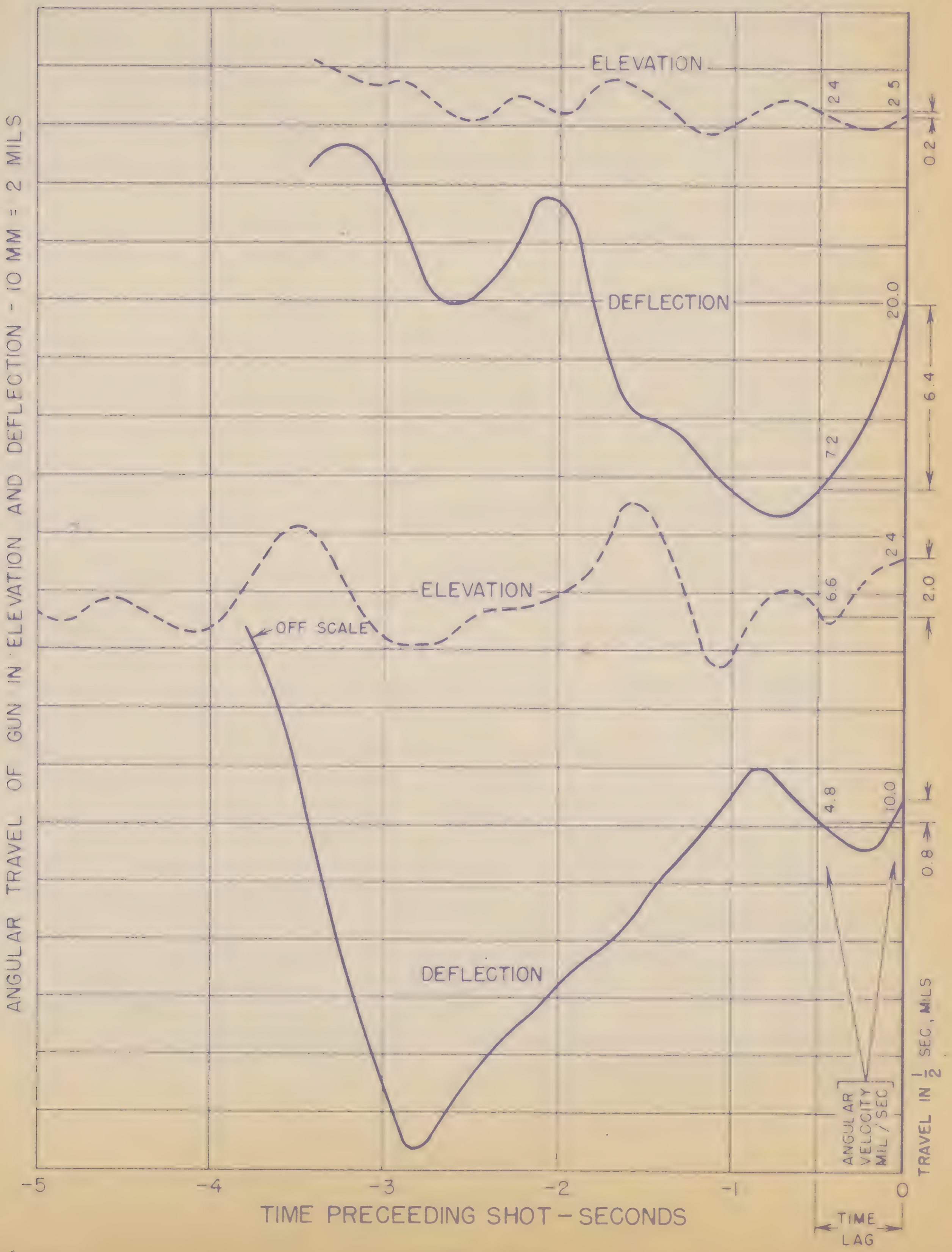
FIG. 14

FIG. 15 a

ANGULAR TRAVEL OF GUN IN MOVING FIRE WITH GYROSTABILIZER
RECORDED MOVEMENT PRECEEDING SHOT-1000 YD. RANGE



Incl #2

FIG. 15 a

FIG. 15 b

ANGULAR TRAVEL OF GUN IN MOVING FIRE WITH GYROSTABILIZER
RECORDED MOVEMENT PRECEEDING SHOT - 1000 YD. RANGE

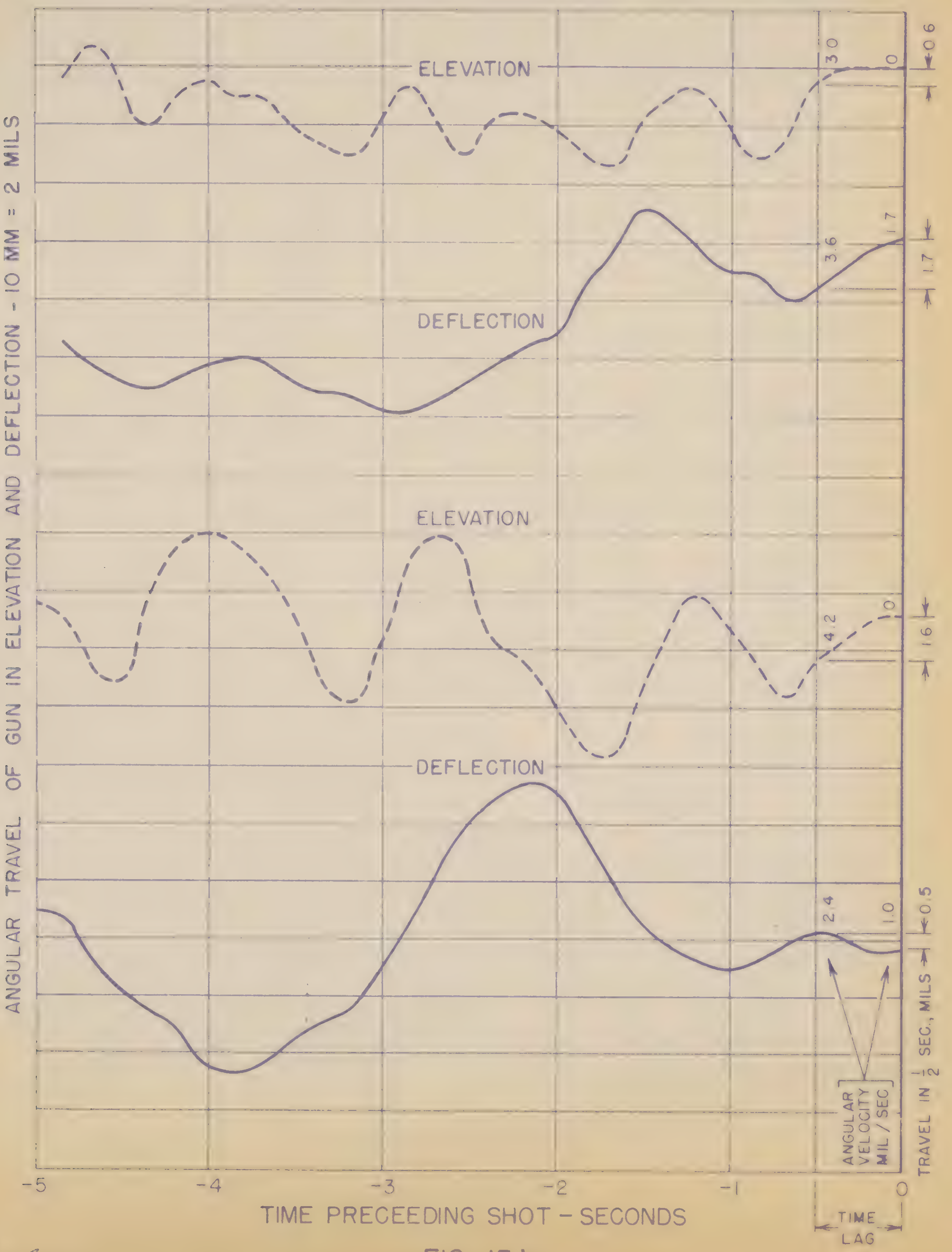


FIG. 15 b

Chart #2

FIG. 15 c

ANGULAR TRAVEL OF GUN IN MOVING FIRE WITH GYROSTABILIZER RECORDED MOVEMENT PRECEEDING SHOT - 1000 YD. RANGE

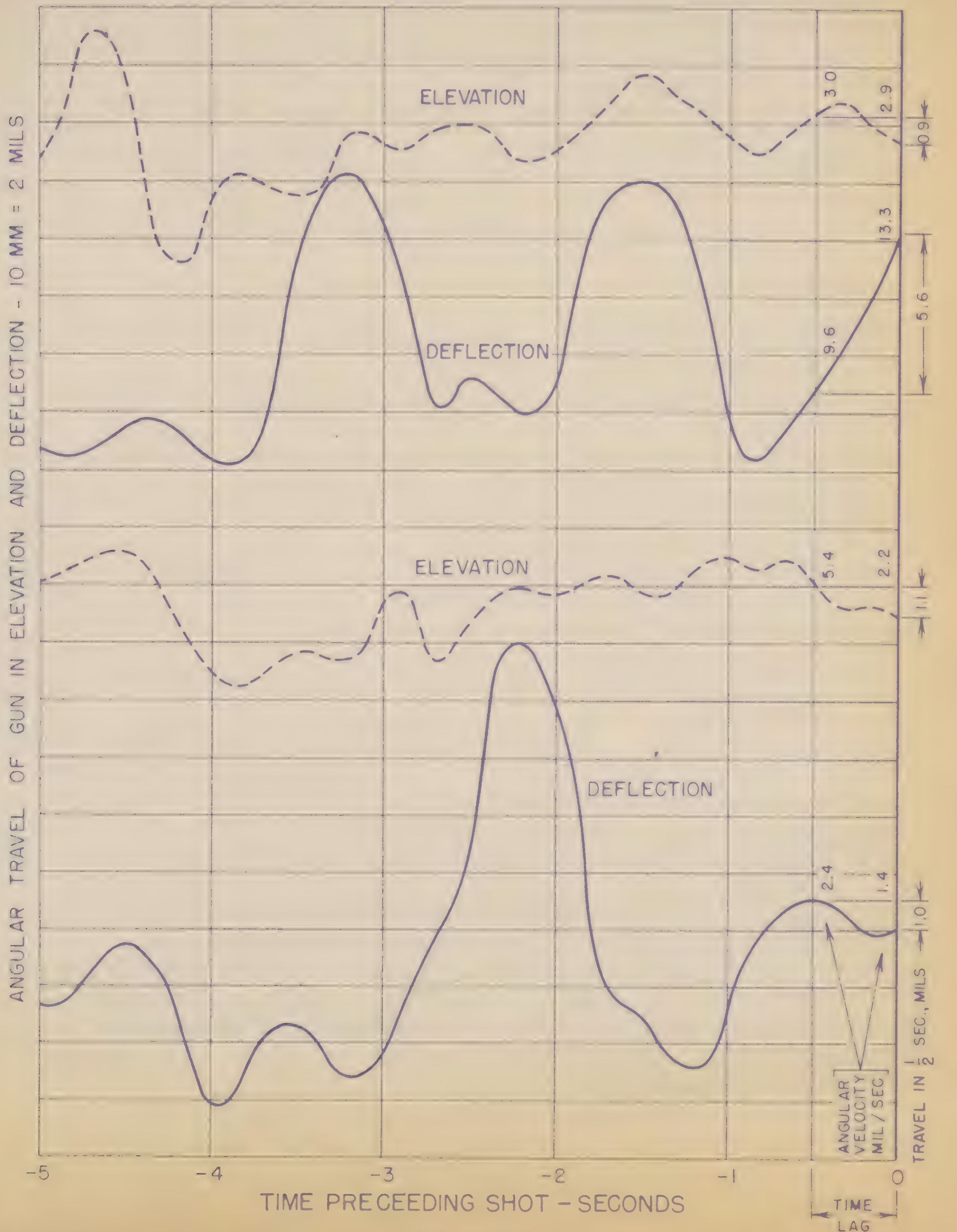


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FIG. 15 c

FIG. 15 d

ANGULAR TRAVEL OF GUN IN MOVING FIRE WITH GYROSTABILIZER
RECORDED MOVEMENT PRECEEDING SHOT-1000 YD. RANGE

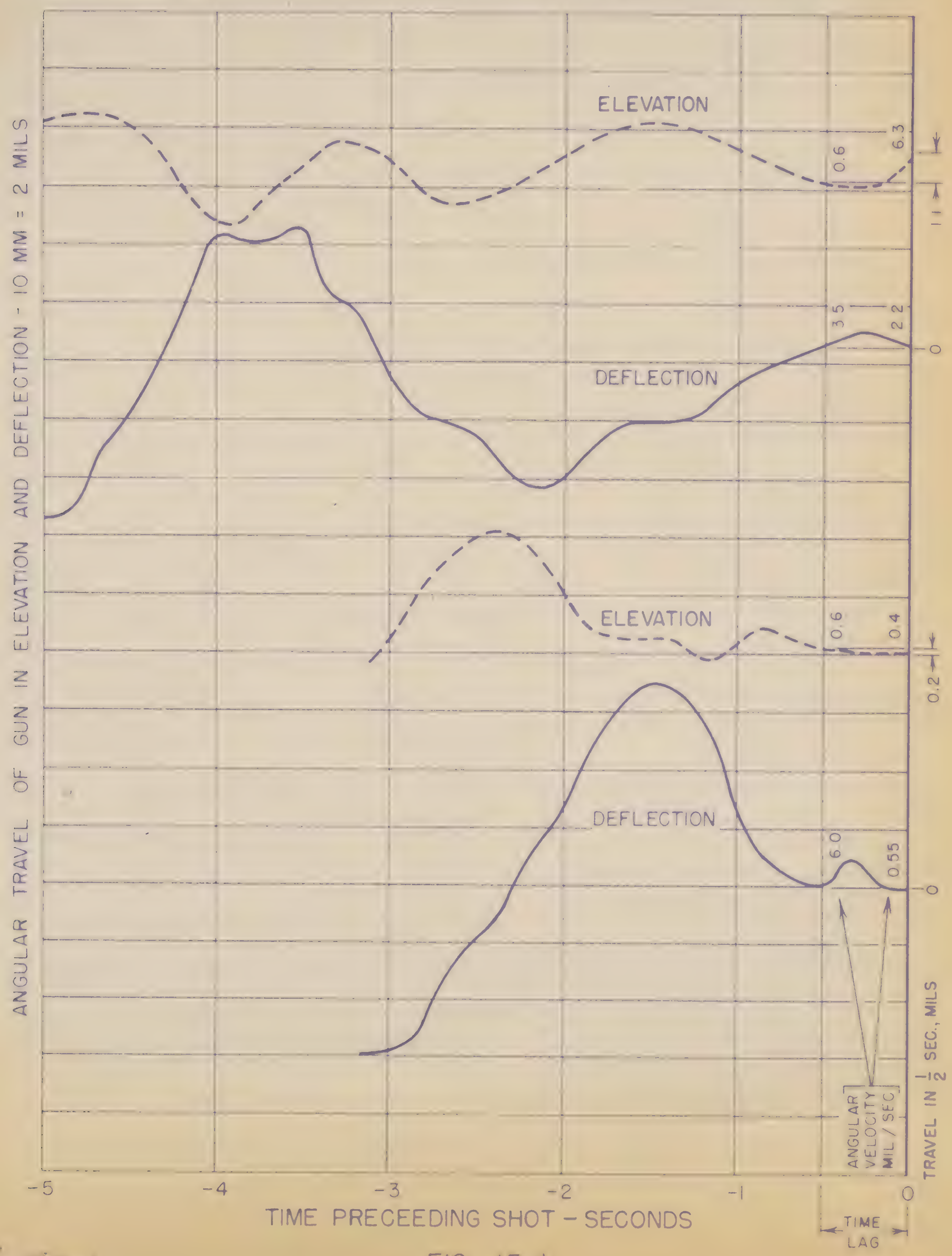

FIG. 15 d

FIG. 15 e

ANGULAR TRAVEL OF GUN IN MOVING FIRE WITH GYROSTABILIZER
RECORDED MOVEMENT PRECEEDING SHOT–1000 YD. RANGE

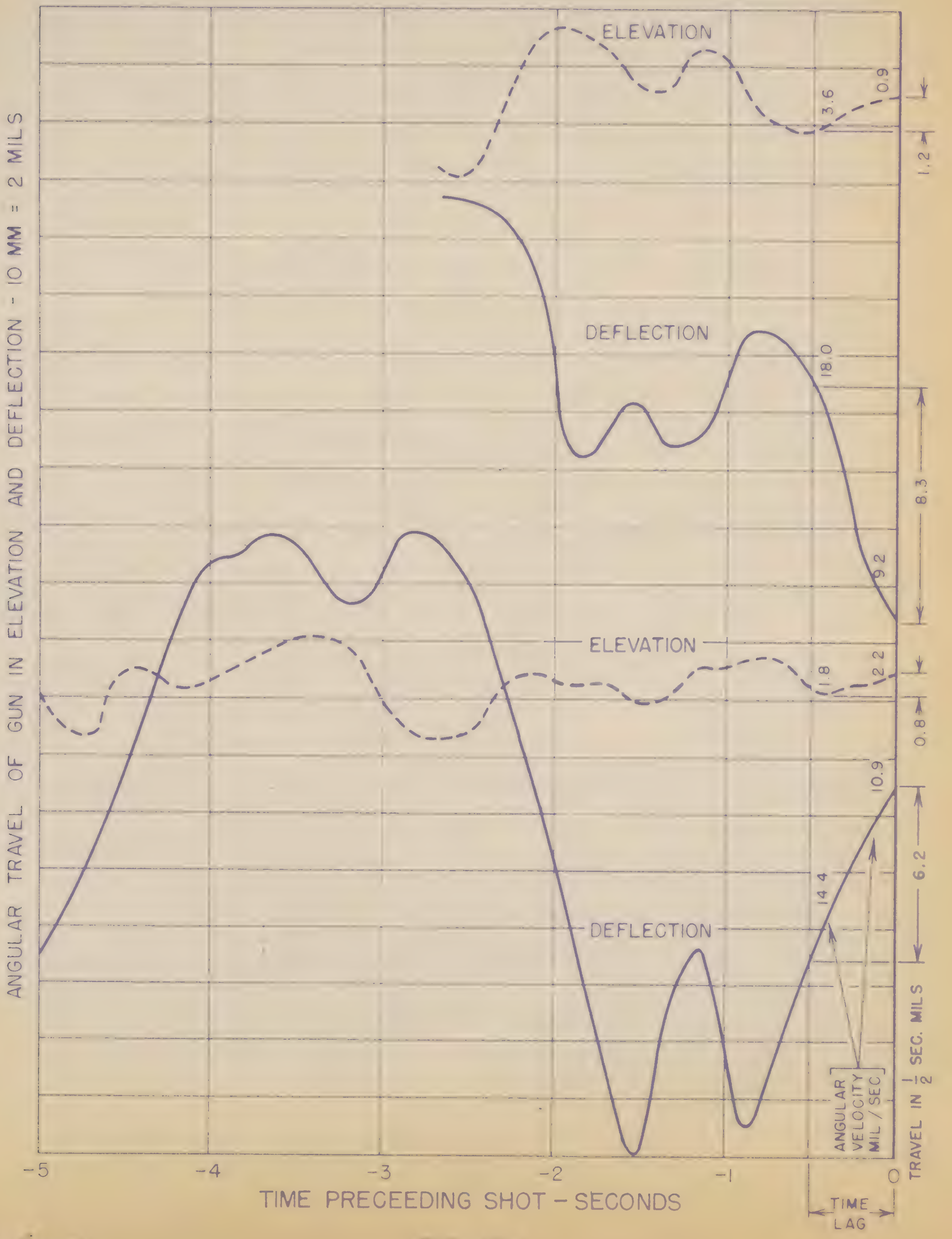

FIG. 15 e

FIG. 15 f

ANGULAR TRAVEL OF GUN IN MOVING FIRE WITH GYROSTABILIZER
RECORDED MOVEMENT PRECEEDING SHOT - 1000 YD. RANGE

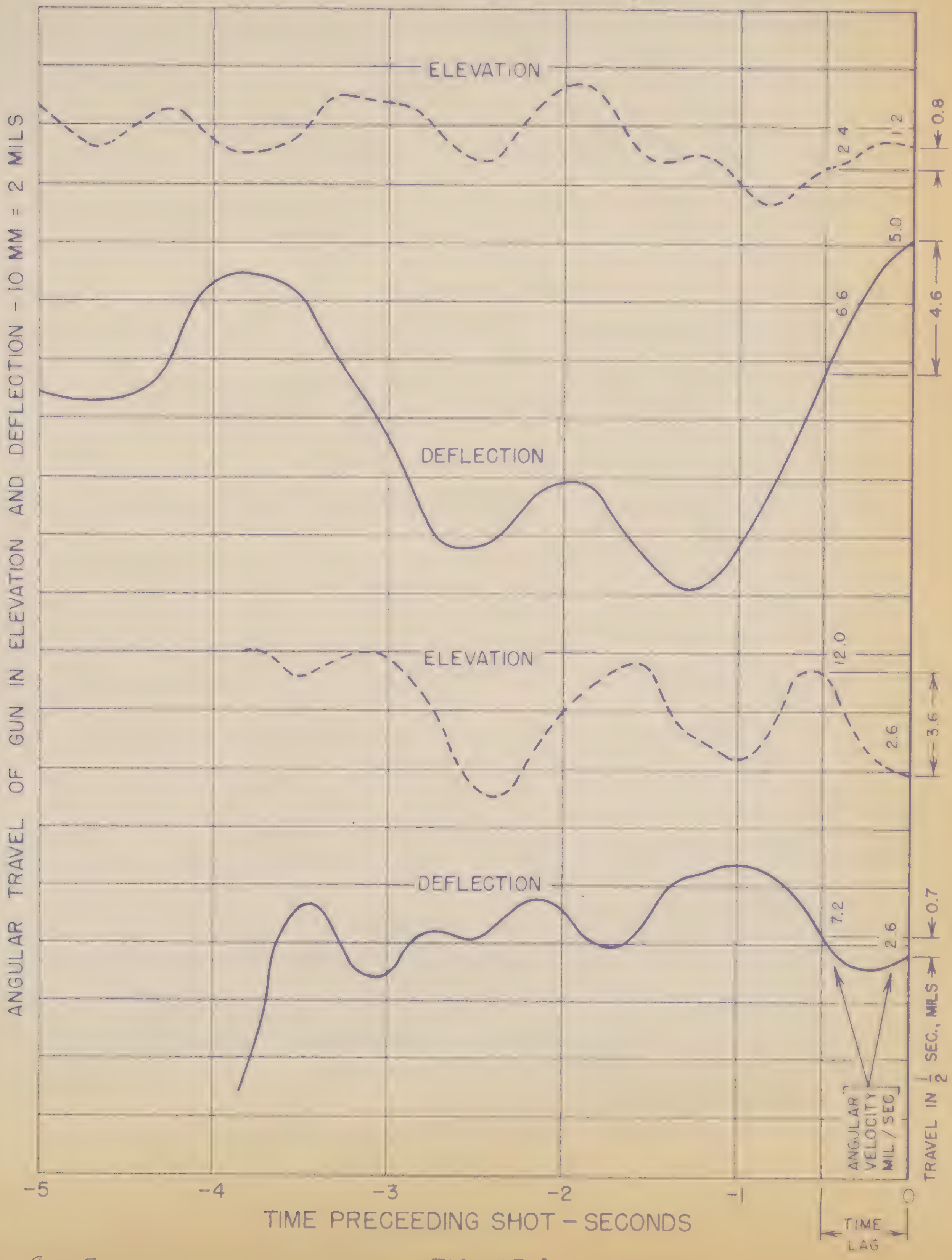

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FIG. 15 f

FIG. 16 a

ANGULAR TRAVEL OF GUN WITH GYROSTABILIZER
RECORDED MOVEMENT ON HARD ROAD SURFACE (DRY RUN)

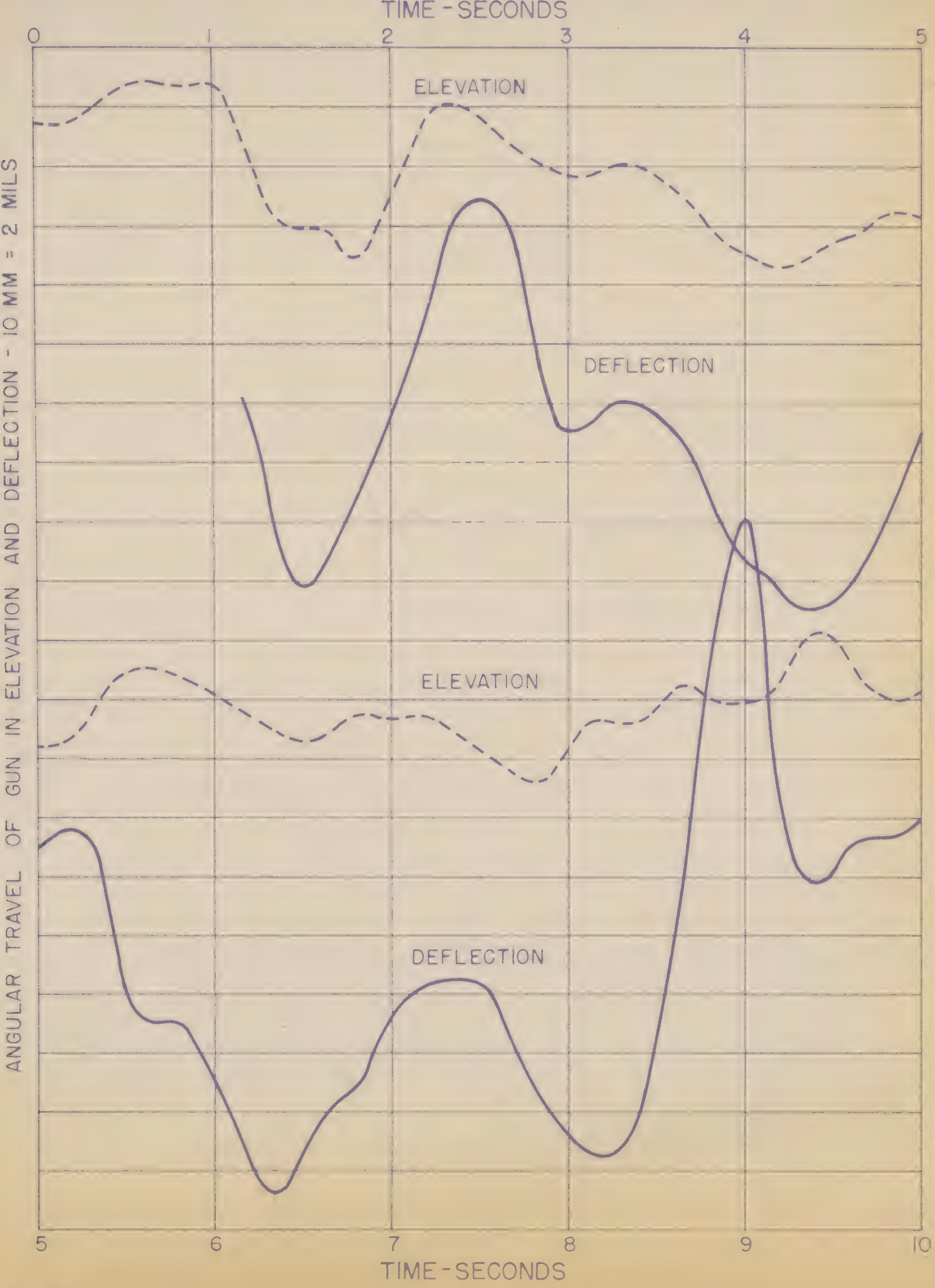

FIG. 16 a

FIG. 16b

ANGULAR TRAVEL OF GUN WITH GYROSTABILIZER
RECORDED MOVEMENT ON HARD ROAD SURFACE (DRY RUN)

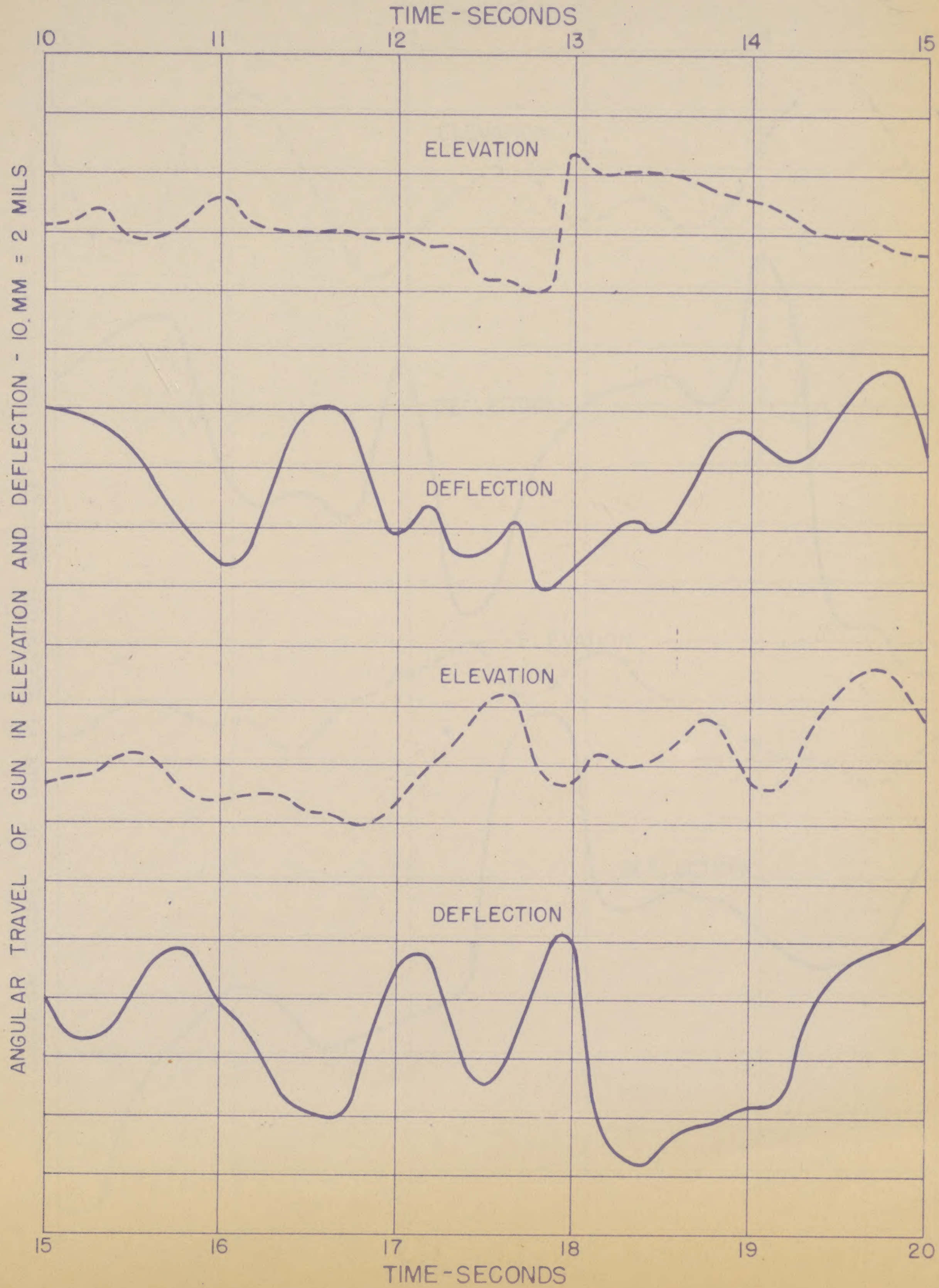

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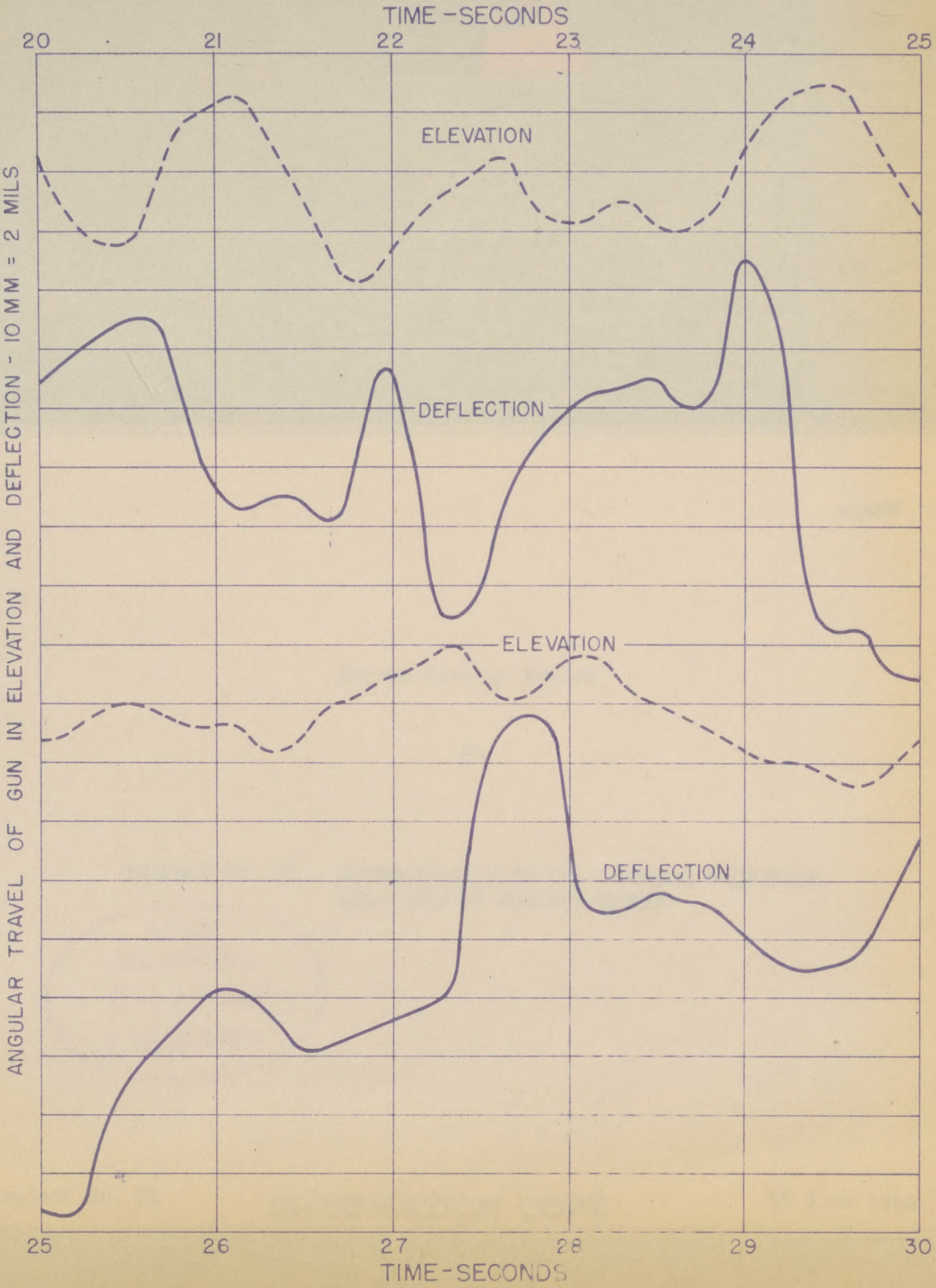
FIG. 16 b

FIG. 16 c

ANGULAR TRAVEL OF GUN WITH GYROSTABILIZER
RECORDED MOVEMENT ON HARD ROAD SURFACE (DRY RUN)



Incl # 2

FIG. 16 c